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Metal Progress

Ernest E. Thum, Editor

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Cover engravings, representing a Black Widow night fighter, were kindly loaned to *Metal Progress* by Pesco Products Co., Division of Borg-Warner.

AMERICAN SOCIETY for METALS

By Richard Doughton, Jr.,

Formerly Engineer Officer
U.S.S. Springfield

Naval Engineering Duty in Wartime

THE DUNGAREE NAVY, black gang, snipes or whatever you may call us, is not a cut-throat gang of swashbucklers. They're good fighting men, and I am proud to have been an engineer in the Navy in wartime. They do a routine job, underway or at anchor, whether steaming quietly at economical speed or feverishly answering bells when the Old Man is twisting and turning the ship, from "Ahead Full" to "Emergency Astern" to "Ahead Flank" in a matter of seconds, 30° right rudder to 30° left, dodging a torpedo attack, or evading the suicidal dive of a Kamikaze. To them, all that matters is the plant — how it operates, how well it runs.

Of all the engineers only the Smoke Watch far aloft can see any action. He warns the fire rooms when smoke from the stacks is white or black — for smoke, you see, helps a target-happy enemy to spot you. The rest of the gang are below, secured under armored decks and hatches, in fire rooms or engine rooms, at steering aft, or in a repair party. *Their* only contact with the battle is by sound — the sound of our guns, the deep boom of the main battery, the harsh slam of the 5-in., the sharp bark of the 40's and the irregular staccato of the 20's. (You don't like to hear the 20's — that means Bogies are coming in close.) Sounds of heavy explosions, sounds of hits! The sound of the Battle Announcer's voice; he is on the Open Bridge, broadcasting through the ship's general announcing system. Some of his remarks are not too reassuring: "Torpedo wake on the port bow!" "They've leveled off at about 10,000, coming in from six o'clock in the formation." "He's diving on us!"

The engineer sweats it out below, knowing well that a hit in his area may get him from fragmentation, concussion, flooding, or escaping steam. Explosions may buckle the hatches, sealing his space permanently, too long for him to escape. But you couldn't get most of them to trade places with the deck force at any price. They're engineers.

But it's not all battle — in fact, it's little battle and much preparation, so my effort will be to touch briefly on the great mass of problems confronting the Engineer Officer of a major combatant ship and some of the more common efforts to overcome them. They are purely personal observations of the Navy and naval engineering and there will be nothing startling, revolutionary nor especially original in them. It was very difficult to become concerned with abstract problems while engaged in continuous wartime operations. These notes have been jotted down, as they came to me, sometimes at Main Engine Control waiting between air attacks or in odd moments during the infrequent overhaul periods. I hope that those who know little of the Navy and of naval engineering will not be too bored, and those who *are* familiar with these matters will not be too critical.

My advent into naval engineering with the fleet was not that of the usual Reserve Officer. I did not attend any of the Navy's indoctrination schools for Reserve Officers; I did not just happen to be assigned to engineering duty; I do not hate the sea! I wanted engineering duty, went to sea at my own request, and was pretty well aware of what that would mean. My first association with the Navy was during the construction of the U.S.S. Akron (ZRS 4) at the Goodyear-Zeppelin Corp. in Akron. The senior inspector of naval aircraft stationed there was Lieutenant Commander T. G. W. Settle; by the fortunes of Navy life, 15 years later Rear Admiral Settle broke his flag as ComNorChinaFor on my last ship, U.S.S. Springfield!

Later association came at the Fore River Plant of the Bethlehem Shipbuilding Corp. at Quincy, Mass., where I worked for several years in the sheet metal, pipe and boiler shops — an invaluable apprenticeship for the future.

When a commission in the U. S. Naval Reserve was granted me, I was at a desk in the War Production Board. Active duty orders sent me to the Bureau of Ships, where I did much the same work as I had done at W.P.B. Since I had expected sea duty — or at least something directly connected with shipbuilding or advance base repair duty — the desk job was a little disappointing, but soon came a billet as B (Boiler) Division Officer on the battleship New Jersey. After a year I was ordered off that ship to be senior assistant engineer and later engineer officer of the U.S.S. Springfield, a new light cruiser of the Cleveland class.

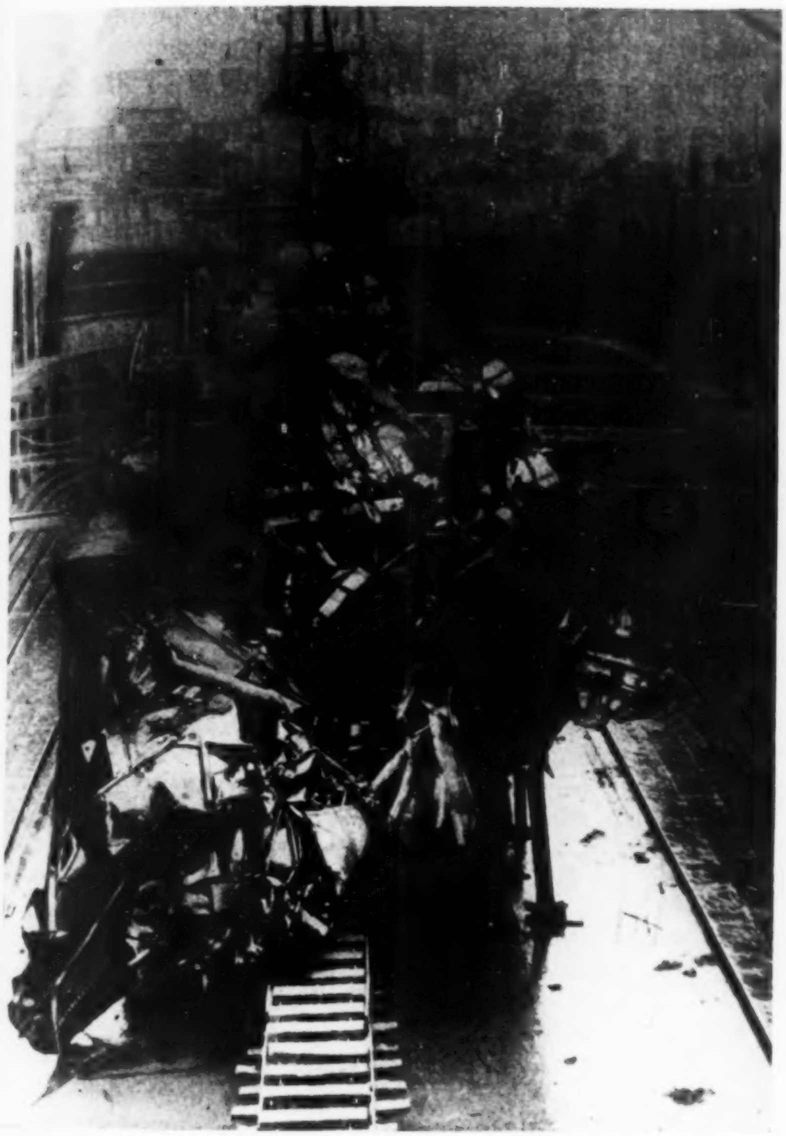
If you have noticed, I have referred several times to *naval* engineering rather than to marine engineering. This has been deliberate. The marine engineering installation moves freight, passengers or mail from some place to another place, either on a definite schedule (as in the highly organized fruit, oil or ore shipping trades or the luxury liners) or in the more-or-less roving spirit of the tramp, seeking cargoes where they may be found, taking them where they will go. The naval engineering plant has only one job — to move a floating gun platform into enemy waters, deal out death and destruction, and then get the hell out of there fast!

They Have to Be Tough in the Navy. This British destroyer, H.M.S. Javelin, was torpedoed at bow and stern and still managed to get to dry dock. (Illustrations

In the first place, the sea-going naval engineer is almost literally at the mercy of his shore-based brothers. It cannot be stressed too strongly that the engineers on the staffs of the supervisor of shipbuilding (SupShips), the inspector of naval materials (InsMat) and the inspector of naval machinery (InsMach) are every bit as important to the engineer officer of a combatant ship as are his best warrant officer and the bull C.P.O. Rigid adherence to well-established inspection standards by the InsMat on materials and components, by the InsMach on machinery units, and on installations and testing by the SupShips can mean the difference between life and death to the fleet unit which must depend on its power plant to take the ship into range, inflict punishment on the enemy and then get out again quickly and safely.

Wartime Substitutes

In these past few years, the shake-down cruise has been the most important period in the life of the new ship. If design deficiencies or constructional weaknesses or errors are not detected then, they are obviously potential causes for future disaster. In our ships there have been but few design deficiencies and those of relatively slight importance — and even those few were detected in operations prior to combat. Constructional errors will probably occur even under the ideal conditions of leisurely peacetime building schedules. The lowered applications of the existing standards due to the fast production requirements



courtesy G. A. Bassett, from his paper "The Repair and Upkeep of H.M. Ships and Vessels in War", presented to the Institution of Naval Architects last April)

of wartime, and the shortage of genuinely first-class mechanics in the yards, occasionally have caused difficulties. Other wartime matters have proven troublesome: Scarcity of materials or components may require that substitutions or alternates be adopted which in peacetime would not even be briefly considered. One such expedient, occasioned by the extremely critical shortage of high-grade tin, was in main engine bearings, through reduction of the tin content of the bearing metal and replacement of tin as the bonding agent by lead. Results were not too satisfactory and many of the substitute bearings had to be replaced. Another general example of alternate practices forced by material shortages is in the use of brass, bronzes or carbon or low alloy steels in certain applications which normally use copper-nickel alloys or chromium-nickel steels. Usually, the price was known in advance, and the saving in higher alloys was considered to be worth the cost of increased erosion or corrosion.

There have been instances where the substitute proved equal to or better than the original specification. This, I believe, was true of propulsion shafting for certain small craft — LCT (5), LST, 180-ft. AM's and PCE's and some YMS classes — in which normalized carbon steel hot rolled bars, turned and polished, or ground and polished, were used in lieu of forged shafting. Adoption of such an alternate was forced by the shortages of forge shops and long engine-lathes. Deficient physical properties, mainly in torsional tests, had long been the major objection to rolled bars; when steelmakers demonstrated to the Navy Department that the torsional properties of rolled bars for applications of this nature were actually better than those of forged shafting, a set of specifications permitting their use was adopted. The only technical difficulties encountered were in the matter of straightness of the shafting in the way of the journals; mutually satisfactory tolerances were agreed upon by representatives of the steel supplier, the Navy Department, the machine shop which had contracted to finish-machine the bar stock, and a few of the yards. It is also interesting to know that at least one class of ship which employed a variable pitch propeller used normalized carbon steel seamless tubing with an extremely heavy wall for propulsion shafting in lieu of hollow-bored forged shafting.

Repairs Underway

Extended operating periods with little time for routine maintenance and overhaul of machinery are the cause of most difficulties afloat. The constant operations of a wartime Navy made it necessary to utilize every spare minute for work on pumps, valves and piping. Every time we

dropped the hook, the gang worked without rest until ordered to get underway again on some part of the plant. And all too frequently we performed major repair work while underway. On a fighting ship you cannot allow any piece of equipment to remain out of commission; it may cost you your life and all your mates'.

Boiler main feed pumps have long been a serious problem to operating engineers from erosion of the horizontal joints between casing-halves in the way of lands of casing rings, diaphragms and bushings. These pumps take suction from a feed booster pump which delivers feed water at 50 psi.; the main feed pumps deliver feed water to the boilers at 750 to 800 psi. Erosion of the pump casing, then, results in loss of feed pressure to the boilers — and *that* ain't good! The cause for this has been ascribed to the corrosive properties of pure feed water, aggravated by the high velocities and necessarily high differential pressures. This corrosion-erosion became the subject of much study, resulting in a decision to change the pump casing specification from Class B cast steel to a chromium-nickel steel casting for future requirements and for replacement of eroded casings.

Fine, but out in what have been lightly termed "the forward areas" most of us repaired our own pumps by undercutting the eroded parts and then building them up with 25-20 Cr-Ni welding electrodes. No, we didn't preheat the casings before welding and we did not stress-relieve after. When there is only a short time available or there is no repair ship in the area, the job must be done by the ship's force, and few ships have heat treating facilities of this nature.

In the fire-and-flushing pumps erosion is again a serious matter. Here, however, it is not the pump casing but it is the casing wearing rings, impeller wearing rings, and impeller nuts which are affected. The usual brass or bronze rings and nuts are good for about four months only before erosion increases the clearances (with corresponding loss of discharge pressure). The grades of monel usually available in the forward areas are seldom the erosion resistant types. I wanted K-monel, heat treated to a minimum of 300 Brinell, but it was seldom to be found.

The spare parts allowance of the engineering department is one of the most important matters to the engineer at sea, primarily because of the great multiplicity of necessary items. You can't take everything with you and sometimes the estimates are wrong; the actual failures may not be the ones anticipated. Further, the original spare parts allowance may have been based on service much different from wartime operations.

In addition to a need for a simplification of the spare parts requirements, the production problems of wartime have also clearly indicated a necessity for some standardization of design in many types of equipment. The multitudinous variety of styles, types and sizes of ball bearings is an outstanding example of this need. Similarly, reduction in the number of piping, valve and fitting sizes, with attendant simplification of gasket types and sizes, seems desirable. Entire standardization of naval engineering equipment is neither practicable nor desirable; for one thing it would discourage the industrial competition which has contributed so largely to the Navy's success by its continually evolutionary developments. An example of a policy which did make sense, to my way of thinking, was the joint War Production Board and American Iron & Steel Institute's work that developed the National Emergency triple alloy steel specifications.

Service Shop at Sea

The engineering department is the service department of the ship. In addition to its obvious duties of supplying propulsion and power for gunnery and communications, it handles a hundred other requirements to make the ship a capital city. Light, central heating, telephone service, fresh water — all are the engineers' work. The First Lieutenant runs the plumbing system, but in most ships the flushing pressure is maintained by engineering pumps — salt water is used, of course. The engineers make fresh water for the galleys, for showers and for drinking, in their salt water evaporator sets.

A variety of repair work keeps the machine shop and maintenance gangs running at capacity all day: A broken part for the dish washing machine, a steam leak in the laundry, a burned-out heating element for the Captain's coffee-maker, a slug in the wardroom Coke dispenser, a hot-running scuttlebutt (drinking fountain to landlubbers) — or someone leaves a telephone receiver off the hook!

The magnitude of the engineer officer's responsibility is best described by U. S. Navy Regulations 1920, Article 784:

> "The engineering officer of the ship shall be responsible for the care and maintenance and proper operation of all machinery in the ship under the cognizance of the Bureau of Ships except radio and sound equipment. . . . He shall be responsible for the care and maintenance of the steering engine and anchor engine. He shall be responsible for so much of the operation of the steering engine and anchor engine as relates to preparing them for use, supervision during use and securing after use. . . . He shall be responsible for the care and mainte-

nance of other power driven machinery units under the Bureau of Ships and of electrically operated navigational instruments, aids and apparatus. . . . In addition, he shall be responsible for the care, maintenance and operation of such other power operated units of equipment with attendant control apparatus as may be specifically assigned him by the commanding officer."

A large order. Literal compliance with it is virtually an impossibility for most engineering departments, on the basis of an inadequate number of personnel alone. Actually, personnel from the deck sections operate the boat and deck winches, airplane crane, or anchor engine, with an engineer standing by; gunnery operates the ammunition hoists and turret training gear; the supply department's commissary branch operates galley, pantry and scullery gear; its ship's servicemen specialists are in the laundry, cobbler and tailor shops or soda fountain.

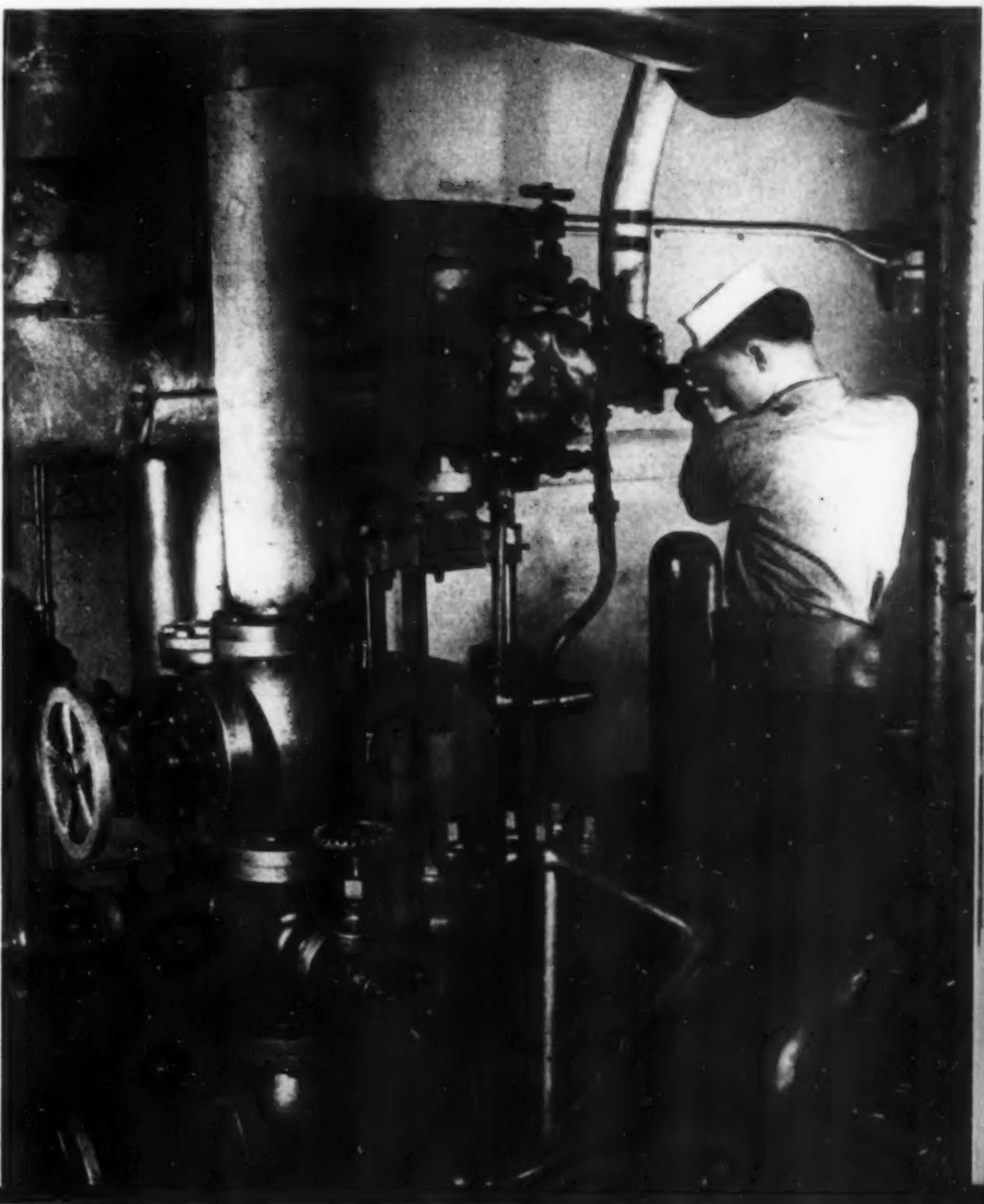
Most of our efforts were frankly makeshift, but when you have machinery derangements in the forward areas, you can't go to a Navy Yard and requisition what you need. If you don't have the part in your spare parts allowance, you repair the old one or make a new one. As I said previously, you cannot allow any piece of equipment to remain out of commission, as it might mean your own and your ship's life.

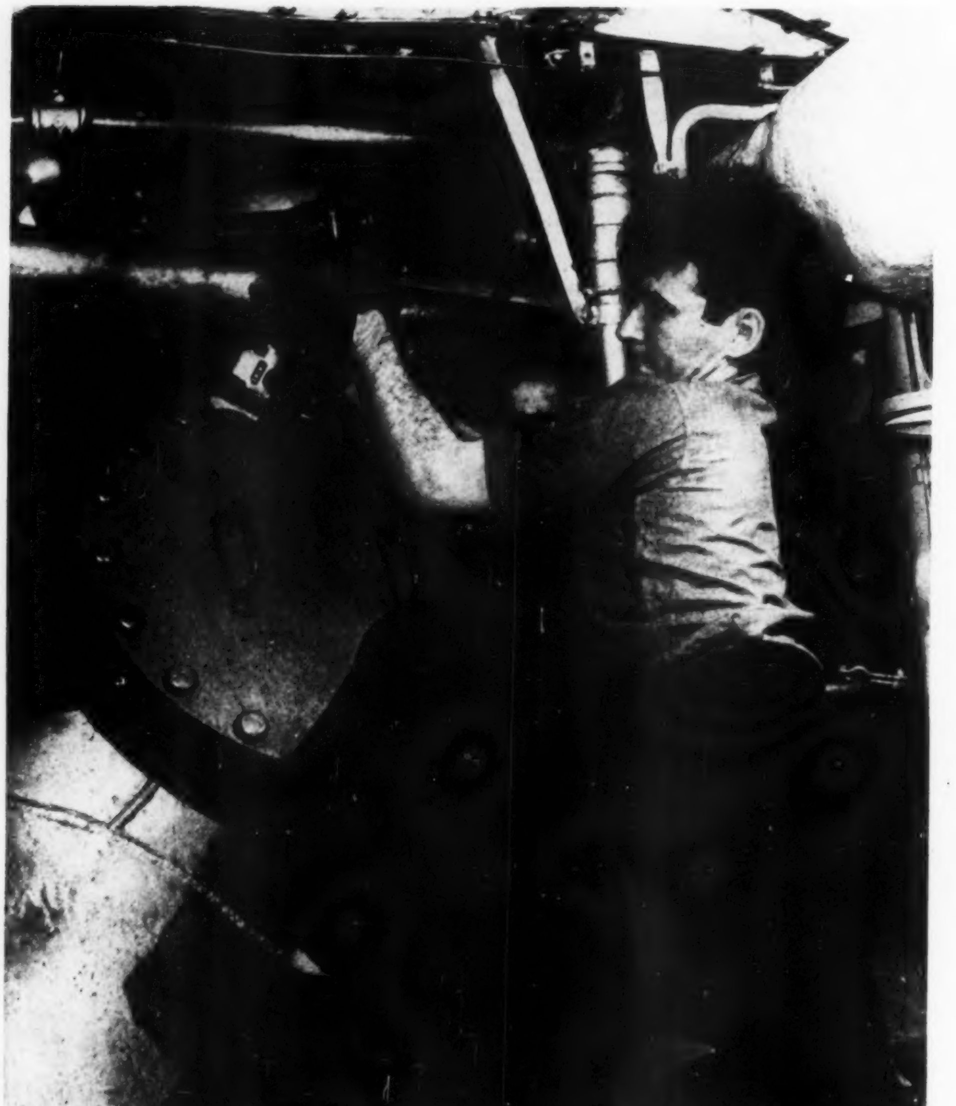
Like all ships we stocked up as best we could on bar stock of various sizes and shapes in mild steel (about S.A.E. 1015), drill rod, 18-8, carbon-moly alloy steel bars. Small amounts of 18-8 and soft iron sheets. Brass, copper and monel bars and sheets. Low and high carbon steel electrodes, 25-20 and 18-8. We did tricks with that small stock! We made valve stems, pump shafts, gun parts; we welded steam lines, and tanks; we

Practical Metallurgy in the Engine Room

You have possibly been wondering what place there was for metallurgical engineering, after the things I have been recounting. Well, there is a real place for the metallurgist and a real use for any metallurgical information that happens to lodge in the memory of any engineering officer. The metallurgist, as a specialist, would undoubtedly be welcomed aboard a repair ship or tender. Repair ships, tenders, and some large carriers and battleships have a small foundry and a blacksmith shop in addition to the machine shop. My last ship, a 10,000-ton light cruiser, has machine shop, metalsmith-coppersmith shop, and welding and flame cutting equipment. We rigged up our own melting equipment and were doing some heat treating. (By that, I don't mean that we had an induction furnace and a line of salt baths and controlled atmosphere furnaces with recording pyrometers, but we were able to do a lot of things that are not done on many ships.)

Pumps (Dozens of Them) Require Constant Attention. Handling water (fresh and salt) at pressures up to 800 psi., they are literally the heart of the ship. (Official U.S. Navy photograph)





"There's One That Won't Come Loose Again!" The seaman replaces the inspection hole cover on a condenser. (Official U.S. Navy photograph)

brazed high pressure oil piping, repaired typewriters, gages, air conditioning units. It was a lot of work!

The melting equipment I mentioned awhile back is an example of using whatever is at hand. The necessary use of dissimilar metals in the construction of valves, or lube oil coolers, or salt water systems in general, quite naturally results in electrochemical action, galvanic or electrolytic corrosion as you may prefer to call it. To combat this, it becomes advisable to localize it by deliberately installing a material which has a greater attraction for this attack, such as a cast iron waster piece or spool, being prepared to replace it periodically. If the designed shape or size or accessibility makes the use of cast iron spools impracticable, zinc pencils or plates are installed.

We started with what seemed to be a generous supply of ½, ⅝, and ⅞-in. round zinc (drawn) bars and ½-in. zinc plates. Operating in the tropical waters of the Pacific increased the rate of corrosion far beyond all estimates, and when we had used the bar stock, there was no more to be had in the area. We were about to use the plate stock, milling pencils from them, not only wasting scarce zinc but requiring considerable shop time. Also, we would eventually run out of plate stock!

Fortunately we met a repair ship that had a small iron foundry and also had a stock of spelter. We had them cast us two iron plates, 10x10x2 in.; we faced off these plates for a metal-to-metal fit and then drilled ½, ⅝, and ⅞-in. central holes to a depth of 8 in. while the plates were clamped face-to-face. That made a permanent mold. For melting, we used a cast iron solder pot set in a hearth made from spare boiler bricks heated by a Hauck oil-burning torch using diesel oil and low pressure air. The set-up worked, too; we even made zinc pencils for other ships! The only machining necessary was to thread one end of the rough pencil. (We planned to try casting pencils complete with threads!) The same melting rig was used for bearing metals.

Heat treating facilities were no more elaborate. The same diesel oil torch was used and the same hearth. All heating and drawing temperatures were judged by eye, and I could never be certain of results so we ran test pieces first to determine whether to quench in air, oil or water. Heat treating was done to aim at strengths or

hardnesses — except of course for items which required only annealing, such as low carbon steel for gaskets.

There were no laboratory facilities, no Brinell or Rockwell hardness testers, no tensile machines. All comparisons had to be made by hardness approximations, using a set of triangular files which had been tempered, back in the States, from 400 to 1050° F. and then brinelled. By a crude scratching test, hardness approximations were obtained from which tensiles were hoped for! Elimination by scratching the test pieces until one file would scratch and the next would not, sufficed for the mechanics of the test.

Most of the heat treating was for valve stems, shear pins and the like; we also did some stress relieving or annealing on some welded parts. One small job of some possible interest was the shaft for a small pump. The original shaft had cracked and there was no spare available. I assumed it needed high tensile strength with moderate ductility and a relatively hard surface for the journals, so I had the threads machined off a 1¼-in. stud for jointing high pressure steam line flanges (believed to be Class An steel), and then heat treated the piece. Upon return to the States, I had a check piece of the same material and treatment analyzed and tested mechanically. Results were 0.47% C, 0.81% Mn, 0.29% Si, 0.33% Ni, 0.92% Cr, 0.45% Mo and 0.02% V. The yield strength of the heat treated shaft was 160,000 psi., its ultimate strength was 244,500 psi., 15% elongation in 2 in. and 47% reduction of area. Its hardness was 484 Brinell.

I tried one job of carburizing, outstanding mainly for its lack of success. A freon sealing diaphragm of 0.008-in. "Swedish blue tempered ultra quality" steel cracked, and of course there were no spares on board. Replacements made of spring bronze and of 18-8 lasted only about 24 hr. each. I tried to carburize a piece of low carbon sheet, about 26 gage, by packing it in soot, planning to surface grind to the proper thinness. We will not discuss the results. Finally we met a ship which had a spare diaphragm.

Probably the most important job of all was the Chaplain's gaff; the shipfitters had made one for him but when he used it on a barracuda, the bend straightened out and the fish swam away. We used ¼-in. drill rod, tempered at about 700° F., I think. It worked.

Welding offered some problems, primarily due to inexperience on the part of the welders. Shipfitters, metalsmiths and boilermakers generally acquire a rudimentary knowledge of the art, but there is not sufficient steady work for them to keep their hands in, and in welding technique — as in so many other jobs — there is no substitute for experience. However, it was my good fortune on the U.S.S. Springfield to be with several men who had more than average skill, considering their hours of practice.

Experiment with various grades of welding electrodes in the allowance showed that the 25-20 Cr-Ni seemed easiest to use; it welded in well but did not burn thin sections. While admittedly an overgrading, its adaptability was often of great importance. Light gage 18-8 sheets, for example, were used as division plates in forced draft intakes; butt welds made during installation failed because of vibration. The use of 18-8 rods resulted in burned areas in the light sheets and more breakage; when the 25-20 rods were used, welds were sound and the sheets were not burned. Additional external bracing reduced the vibration and no further difficulties were encountered. Inlay welding of main feed pump casings has been mentioned previously.

Versatility of 25-20

The heat resistant properties of the 25-20 grade were demonstrated in the repair of a badly burned soot-blower head. This was located in the roof of the superheater side firebox, an area of hot furnace gases; it burned so badly that its efficiency was reduced at least 75%. We built up the head with 25-20 electrode, ground it to shape, and reinstalled it with entirely satisfactory service from then on.

A last example of the versatility of the grade is in its application as a hard — or rather erosion resisting — surfacing material for valve disks and steam-trap seats. Steam-cut areas were built up on the contact face with 25-20 rod, quenched in water, rough machined, peened and then ground to finish with a tool-post grinder.

I hadn't done any spark testing since separating some mixed steels in 1937, but I had planned to make up a set of standards next time we were back in Pearl or the States. They would have been useful several times.

In the few years prior to my service in World War II when I was away from ships and naval engineering installations, there had been great changes. I imagine that if another war comes along (and I'll sit *that* one out, from a desk in Washington, please) we'll again have a strange new Navy. Probably gas turbines for propulsion. Completely air-conditioned machinery spaces. All kinds of automatic gear. Electronics gone wild. One thing, however, will not have changed; *men* will still be the most important part of the engineering plant.

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A Method for Evaluating Toughness of Steel

Meaning of Toughness — Toughness is the ability to absorb energy by deformation. It is a property of the material, but one which is greatly affected by the conditions of testing or of loading. If data derived in the ordinary tensile test are plotted as in Fig. 1, where the horizontal scale represents % reduction of area rather than % elongation, the area under such a tensile curve is a quantitative measure of toughness and may be approximated by an equation involving the factors tensile strength and reduction of area.

True tensile loading seldom exists in machines or structures, and tensile failures involving large deformations before failure are very rare. Such accidents represent either a gross error in the design or a considerable unanticipated overload of the structure. Hence, everything beyond about 1% plastic deformation in the tensile curve is very seldom used in service.

What is required is the assurance of a small amount of reserve plastic deformation — not under conditions of tensile loading but under the unfavorable conditions of nonaxial loading when stress concentrators such as notches or sharp changes in section are involved and, often though not necessarily, under shock loading at subnormal temperatures. The purpose of this reserve is simply to allow slight plastic adjustment to level out the load distribution and avoid the formation of a crack which intensifies the stress concentration and reduces the load-carrying area. This point may be easily demonstrated by making static tensile or bending tests of notched specimens of tough and brittle steels and observing the decrease in load-carrying ability of the brittle steel as the strength level or the severity of the notch increases beyond a critical value.

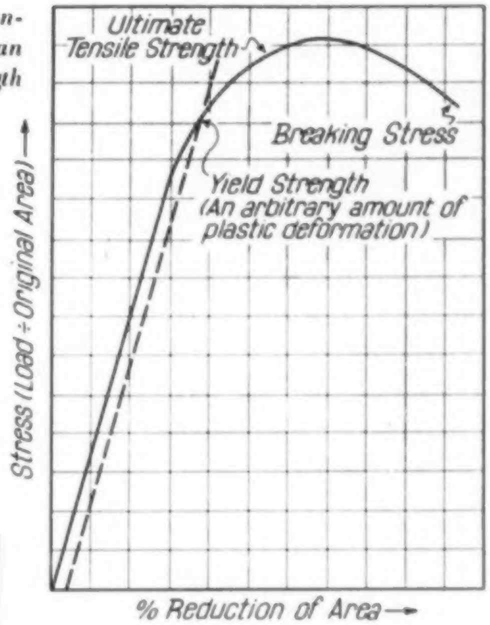
VARIOUS METHODS have been proposed for obtaining a figure of merit which expresses the always-to-be-desired combination of strength and toughness in constructional steels. To mention but a single instance, *Metal Progress* carried in the March issue a data sheet for obtaining a figure of merit used to a considerable extent in the automotive industry, designated as the P value, based upon a weighted expression or combination of tensile strength and reduction of area as given by the formula

$$P = \frac{1}{5}\left(\frac{T.S.}{1000} + 6\,R.A.\right)$$

While the use of the P value for the comparative rating of steels of similar types and heat treatments is not questioned, experience has shown that reduction of area is not necessarily a good criterion of toughness. An alternate method for evaluating and expressing the merit of steel in terms of strength or hardness and notched-bar impact energy is herein suggested. All of the mechanical service properties can be evaluated and except for fatigue can be easily expressed in terms of these two test values. For fatigue strength there is a rather close relationship between tensile strength and polished bar endurance, but there is some evidence to indicate that notched-bar endurance is influenced by toughness as well as strength. Other special tests, of course, are always necessary to evaluate such properties as corrosion and abrasion resistance, strength at elevated temperatures, machinability, and weldability.

*At the time of writing (April, 1946) Mr. Herres was Captain, Ordnance Department, and chief of the welding development section, and Mr. Jones was chief of the specification section of Watertown Arsenal Laboratory. The statements or opinions expressed are to be considered those of the authors and do not necessarily express the views of the Ordnance Department.

Fig. 1 — *Tensile Curve Where the Strain (Horizontal Scale) Is % Reduction of Area Rather Than Conventional % Elongation in 2-In. Gage Length*



To illustrate this point bend bars ½ in. wide and 1½ in. deep, with V-notch 0.08 in. deep and 0.002 in. radius across the narrow edge, were prepared from a single piece of 0.25% C medium alloy steel. They were then heat treated to approximately the same tensile strength, two by quench and draw and two by normalize and draw (see Table I for tensile and impact values). Samples for each heat treatment were bent on a 4-in. span at normal and at low temperatures (see Fig. 2). Breaking loads were recorded as follows:

Table I — Effect of Testing Temperature and Heat Treatment Upon Charpy V-Notch Impact Resistance of 0.26% C Aluminum Killed and Boron Treated Mn-Mo Steel *(a)*

Property	Temperature	Quenched *(b)*	Normalized *(c)*
Tensile strength	+ 70° F.	131,200 psi.	122,000 psi.
	−110° F.	155,100	138,000
Reduction of area	+ 70° F.	62-63%	58-58%
	−100° F.	56-58	54-54
Charpy V-notch impact	+212° F.	55-54 ft-lb.	21-14 ft-lb.
	+ 70° F.	55-55	8-6
	0° F.	—	3-4
	− 40° F.	55-55	3-3
	−100° F.	51-45	—

(a) Analysis: 0.26% C, 1.68% Mn, 0.013% P, 0.021% S, 0.24% Si, 0.33% Mo.
(b) Water quenched from 1600° F., air cooled from 1200° F., resulting in tempered martensite.
(c) Air cooled from 1600° F., then from 1140° F., resulting in pearlitic microstructure.

The quenched and tempered bar: 31,500 lb. at +70° F. and 32,000 lb. at −40° F. For the normalized and tempered bar, 23,000 lb. at +70° F. and 21,000 lb. at −40° F.

If a large total deformation in the tensile test was a guarantee of the required toughness under severe conditions of loading, a minimum requirement for reduction of area in the tensile test would accomplish everything desired. Unfortunately, taffy-like behavior in a tensile bar does not offer any assurance that the metal will behave similarly under more severe loading conditions. There is good reason for this; before a tensile bar has been stressed to the fracture load, sufficient plastic flow has taken place to line up all small inhomogeneities in the direction of flow and the fracture load is thereby raised, permitting still more deformation.

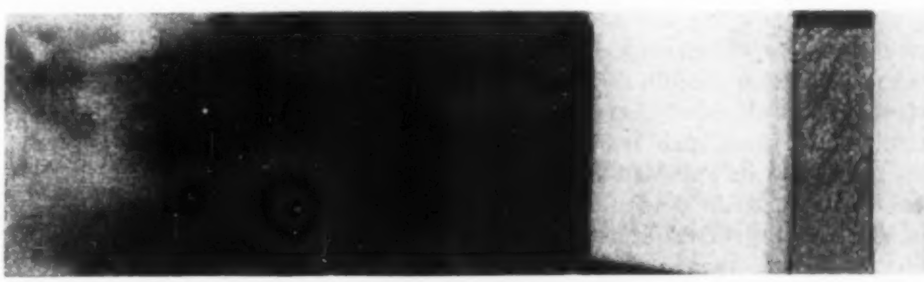


Fig. 2 — *Fractures (Full Size) of Notched Bend Bars of a Steel in Normalized and Drawn Condition (Above) and Quenched and Drawn Condition (Below), Both Broken at Room Temperature*

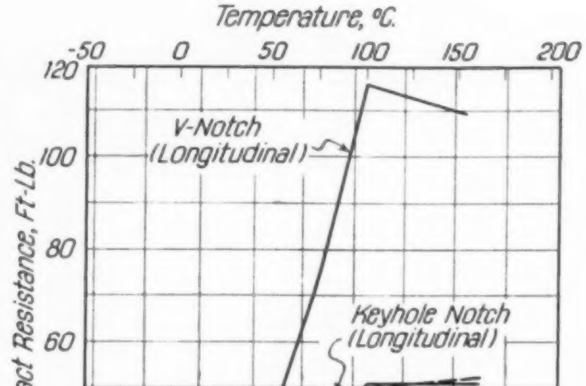


Fig. 3 — Effect of Type of Notch and Direction of Rolling on Standard Charpy Notched-Bar Impact Values (Jackson, Pugacz and McKenna, Transactions *A.I.M.E., 1944)*

A stress concentration, however, may cause the steel to be loaded to failure without opportunity for large plastic flow, and it is under such conditions that considerable differences in the inherent toughness of steel become apparent and are important. These differences are known to be due largely to quality (amount and distribution of nonmetallic inclusions), chemical composition, and heat treatment.

It is generally agreed by testing engineers that the use of notched tensile or bend test bars provides a means of bringing the effect of stress concentrations into the determination of toughness of steels, but extreme care in preparation and testing is required for reproducibility of results. Further, the value obtained relates only to one testing condition and is therefore qualitative in nature.

Other than the method of test (whether tensile, bend, or notched-bar) the other two testing variables — temperature and speed of loading — can also be utilized for determining the toughness of steel. As the temperature of testing is decreased below normal atmospheric temperatures, the yield strength of all steels increases and the rate of strain hardening also increases. This results in an increase in the load or stress after a given amount of plastic deformation and consequently in a more severe test of the toughness. In effect, decrease of temperature is analogous to increasing the strength level of the steel without altering its quality or metallographic structure.

Increasing the rate of loading also appears to raise the yield strength and load or stress after any given amount of deformation. However, at high loading rates, shock waves come into play and may result in local overloadings, difficult to interpret.

Notched-Bar Impact Tests

The use of notched-bar impact tests is a simple, practical, widely available means of testing the toughness of steels under unfavorable loading conditions. The severity of the test may be increased by *(a)* increasing the stress concentration factor (increase sharpness of notch, width or depth dimensions, or decrease breaking span); *(b)* decreasing temperature of testing; or *(c)* increasing rate of loading or impact.

Since it is obviously desirable to use standard testing machines and specimens there are only two decisions to make: First, the type of specimen, whether Izod, Charpy keyhole notch, or Charpy V-notch; and second, the temperature of testing.

The Charpy V-notch specimen has a larger breaking area and a more severe notch than the Charpy keyhole specimen and, therefore, has a greater drop in energy value at a higher transition temperature for steels which become brittle. (See Fig. 3.) A method* which permits rapid machining and excellent reproducibility of notch contour for the V-notch has been

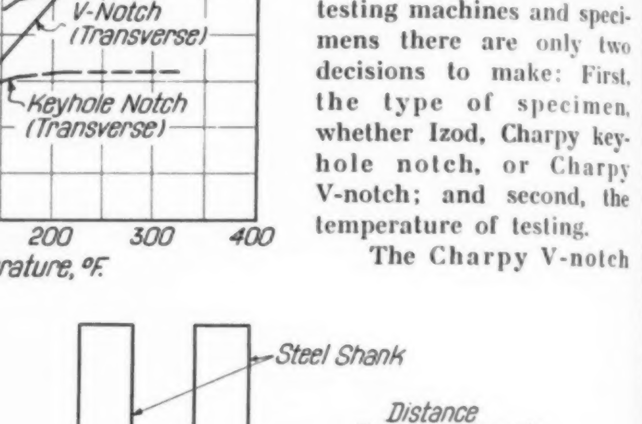


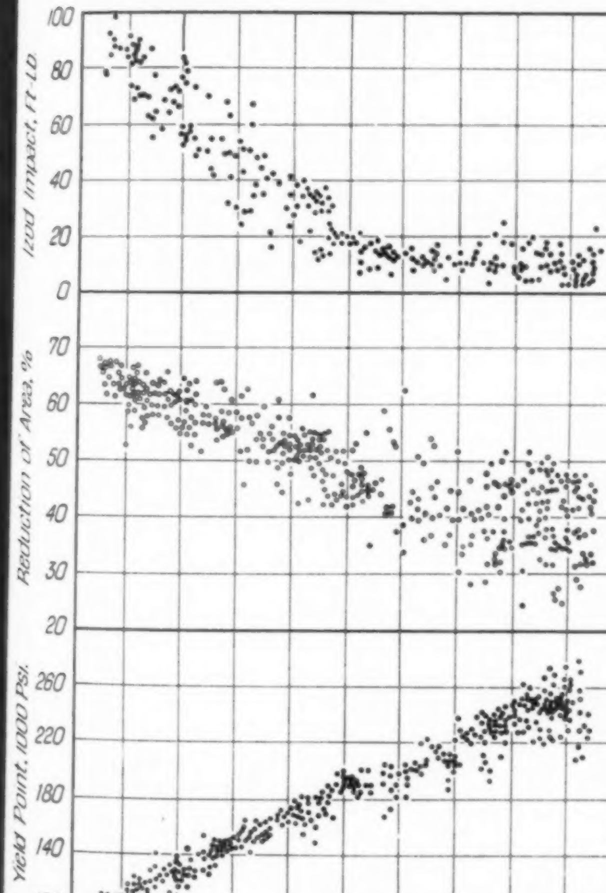
Fig. 4 — Charpy Impact Test Specimen With V-Notch and Carbide Tipped Tool for Milling Notch

*As described in a brief communication in *A.S.T.M. Bulletin* for March 1946, this consists of a simple 45° angle tool bit with cemented carbide insert ground to desired notch dimensions. There is no side rake on this tip. It is set in a milling machine arbor so it acts as a fly cutter with 12° negative rake, thus insuring a high order of wear resistance. Notches have been cut in steel heat treated to C-60; surfaces of the notch are very smooth, approaching a lapped surface. Little cold working and flow of metal is produced.

developed by S. E. Siemen at Watertown Arsenal. The standard specimen, shown in Fig. 4, has been found to be satisfactory for testing a wide variety of steels. The Charpy type test machine is used because it is more convenient, particularly for low temperature tests.

A testing temperature of $-40°$ F. is sufficiently low to be below the transition temperature for practically all steels which give brittle failures in any ordinary service. A test at $-40°$ is also easily made by immersing specimens in a bath of dry ice and alcohol for a period of 15 min. or longer. The specimen can be taken from the bath and broken within a few seconds. Tough steels show relatively little decrease in energy to extremely low testing temperatures (see Table I). In spite of statements to the contrary which have appeared in American literature this test properly interpreted is a reliable criterion of ballistic shock behavior of armor plate. This fact was realized long ago by English metallurgists — see, for example, Harry Brearley's reminiscences, "Knotted String," page 106 to 109.

Fig. 5 — Comparison of Mechanical Properties (Longitudinal Specimens) of a Number of Fully Hardened and Tempered Steels (Patton)



Relation Between Hardness and Strength

Hardness and tensile strength are measurements of essentially the same properties. Conversions between the two have been worked out and found to be accurate within the ranges of errors encountered in ordinary test methods.

A great service has been done for practical metallurgists by Janitzky and Baeyertz and by Patton who have shown the similarity in tensile properties among all alloy steels which have been properly heat treated. Figure 5 is a replot of Patton's data, given in *Metal Progress* for May 1943.

For steels which have been fully hardened during quenching and then tempered there is remarkably small deviation from a constant relationship among hardness, tensile strength, and yield strength (yield-to-tensile ratio is 90 to 95%). Steels which have not been fully hardened during quenching or which are in the as-quenched condition have lower yield strength to tensile strength ratios. Whether this means anything but the absence of an upper yield point in the first case and the presence of quenching stresses in the latter, and whether the yield strength of a tensile bar is important to the service properties of a structural part, are all open to question.

If design is based on yield strength and there is doubt that the steel has been fully quenched, it should be necessary to make only a few tensile tests to determine yield-to-tensile ratio (always remembering that a tensile specimen heat treated as a small bar does not represent a part of larger size). Thenceforth, there is little need for extensive tensile testing when hardness tests will supply the same information at much less expense.

Relation Between Strength and Toughness

The toughness of steel is controlled by *(a)* the amount, form and distribution of nonmetallics; *(b)* the amount, form and distribution of carbides; and *(c)* whether or not the steel has been subjected to tempering conditions under which it may be susceptible to various forms of embrittlement.

The cleanliness of steel and the distribution of nonmetallic inclusions as influenced by hot and cold forging, rolling, or other working operations

have a great effect on toughness under all loading or testing conditions. Variations in cleanliness account for practically all of the scatter in reduction of area values shown in Fig. 5 (which are for specimens taken longitudinally from forged bars). Some steel users who rely on the meaningless security of high ductility values of tensile tests taken parallel to the rolling or forging direction would be dismayed to find that the values for elongation and reduction of area are often cut in half if the tensile tests are made transverse to the working direction.

Similarly, notched-bar impact values are affected by directional properties, as shown in Table II. If it is known that the steel will be used so that all major stresses are parallel to the direction of working,* as in forged bars of relatively small section, it is proper to take longitudinal specimens. However, impact values on forged bars should not be used to represent rolled *plate*. In rolled plate, the best practice is to test toughness with transverse specimens which show the worst effects of directionality and put the proper premium on cleanliness and good cross-rolling.

Sometimes it happens that a lamination or elongated segregation of inclusions will interrupt the mechanism of notch constraint in an impact test and give a specimen with the split or badly stepped fracture (see Fig. 6 and 7). The energy value then obtained has no significance. This effect can be minimized and reproducibility of values can be improved by always notching the specimen perpendicular to the original plate surface.

A fact which has been realized for a long time, but perhaps not as widely applied as its importance warrants, is that the optimum toughness at a given strength level is obtained when a heat treated steel has been first *fully* hardened (quenched out completely to martensite). This is related to the uniformity of carbide distribution in the microstructure and it is possible to obtain toughness values in steels originally of pearlitic or bainitic microstructure comparable to those of tempered martensitic steels only if the carbon content is very low or if tempering has been sufficient to spheroidize the carbides (that is, at very low strength levels).

A comparison of the Charpy V-notch impact values for a 0.25% C medium alloy steel heat treated to give a tempered martensitic microstructure (quench and draw) and heat treated to give a pearlitic microstructure (normalize, air cool) at approximately the same strength levels is given in Table I, which also illustrates the failure of reduction in area to reflect large differences in toughness.

Carbon content also affects the toughness value, but for similar microstructures and strength levels the effect is not large within the usual carbon limits for constructional steels. For example, two medium alloy steels of 0.40% C and 0.25% C could not be distinguished by Charpy V-notch impact values at −40° F., when tempered to the same strength level.

For fully hardened and tempered steels of uniform cleanliness and directional properties a consistent inverse relationship between strength level and toughness as measured by Izod impact at room temperature has been established (see Fig. 5). But the toughness of any given steel does not increase

Fig. 6 — Split Fractures in Longitudinal V-Notch Charpy Impact Specimens

Table II — Influence of Directional Effects on V-Notch Charpy Impact Values at 70° F.

Nature of Steel	Tensile Strength	Specimen Transverse to Principal Rolling Direction	Specimen Parallel to Principal Rolling Direction
Straightaway rolled steels*	137,500 psi.	34-35 ft-lb.	67-64 ft-lb.
	142,000	36-37	70-71
	134,000	43-44	75-76
Cross rolled steels*	132,000	54-49	62-61
	155,000	44-47	46-45
Cast steel, as-cast	110,000	53-56 ft-lb.	
Same steel forged†	110,000		102-122 ft-lb.

*Notch parallel to plate surface.
†From 2x3½-in. section to ½-in. square bar.

*Forged gears and many wrought iron parts are purposely fabricated to utilize the best directional properties.

Fig. 7 — Micro at 600 Diameters Showing Nonmetallic Inclusion Which Caused a Split Fracture in a Longitudinal V-Notch Charpy Specimen (Hurlich)

linearly as strength decreases on tempering. Practically all fully hardened steels show a decrease in notched-bar impact toughness during tempering in the range of 350 to 750° F., as shown in Fig. 8. This is probably associated with the initial stages of precipitation of Fe_3C from martensite. The higher carbon steels show a slight increase in toughness at very low tempering temperatures, probably associated with relief of lattice distortion. (In Fig. 8 note the difference between oil quenched and water quenched specimens.)

Steels which contain alloys such as chromium, molybdenum, manganese, and vanadium, which form complex carbides during tempering, show a second irregularity in the curve of impact versus draw temperature at the same temperatures at which secondary hardening or retardation in softening occurs (see Fig. 9). This is probably associated with the initial stages of precipitation of complex carbides.

Some steels, notably those high in manganese or chromium, show another form of embrittlement if tempered in the range of 750 to 1100° F., or slowly cooled through this range after tempering at higher temperatures (Fig. 10). This is the phenomenon commonly termed temper brittleness; its cause has never been adequately explained.

It should now be evident that a steel which has been tempered under conditions where it is subject to one of the above forms of embrittlement will have a toughness value at a given strength level below that of another steel which has been brought to the same strength level without being subject to any form of tempering embrittlement.

It may be noted in Fig. 5 that impact values for steels whose strength is in the range of 200,000 to 240,000 psi. probably all represent steels embrittled during tempering. At higher strength levels *better* toughness resulted for some of the steels.

By selection of steel composition and tempering temperature it is possible to obtain good toughness values at all strength levels for steels not subjected to any form of tempering embrittlement. This is shown in Fig. 11. Combining the data of Fig. 5 and 11, Fig. 12 is obtained which, it is proposed, may be used for complete evaluation of mechanical properties of steels (within the strength limits covered) in terms of two test values.

Evaluating the Strength and Toughness of Steel

For steels initially fully hardened a hardness test establishes the tensile and yield strength levels quite closely, as shown in Fig. 12. If design is based on yield strength, steels initially not fully hardened will have yield strengths below the value indicated in the chart, and a standard tensile test must then establish the true yield strength.

Toughness is measured by a standard notched-bar impact test specimen broken at −40° F. The toughness may be evaluated as percentage of the impact value indicated by the base line of Fig. 12 at the corresponding strength level, and for specification purposes can be expressed either as this percentage or as minimum energy (ft-lb.) at a minimum tensile strength. Higher toughness, approaching the upper dotted line in Fig. 12, may be obtained by taking specimens parallel to the rolling direction of straightaway rolled plate, but these

Fig. 8 — Hardness and Charpy V-Notch Impact on N.E.8740. Test pieces heat treated, then tested at 70° F. Heat treatment: 1 hr. at 1600° F., quench in oil or water; draw as shown, 1 hr. at temperature, air cool

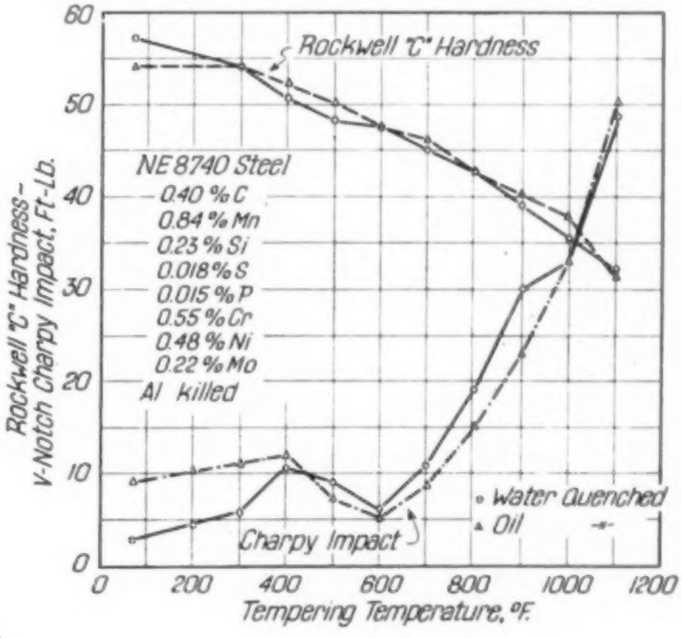


Fig. 9 (Right) — Irregularity in Impact Versus Tempering Temperature, Probably in Region of Secondary Hardening, in Steels Containing Alloys Which Form Complex Carbides. Data from "Vanadium Steels and Irons", by Vanadium Corp. of America, and "Molybdenum in Steel", by Climax Molybdenum Co. Analyses:

ELEMENT	MN-V STEEL	NI-CR-MO STEEL
Carbon	0.23	0.41
Manganese	1.68	0.62
Phosphorus	0.025	0.019
Sulphur	0.017	0.016
Silicon	0.25	0.20
Nickel	—	1.57
Chromium	—	0.51
Vanadium	0.18	—
Molybdenum	—	0.15

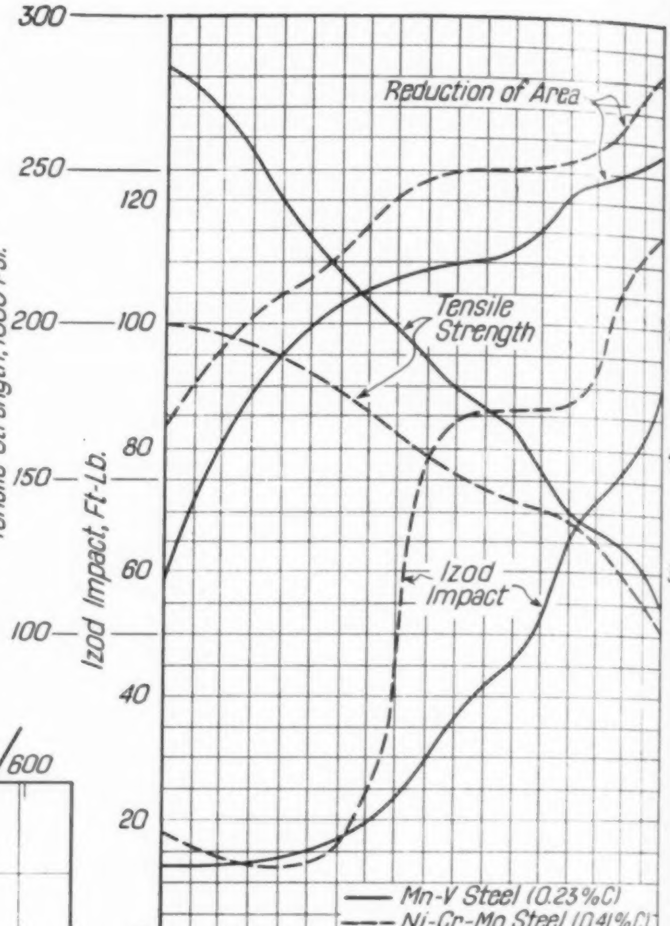
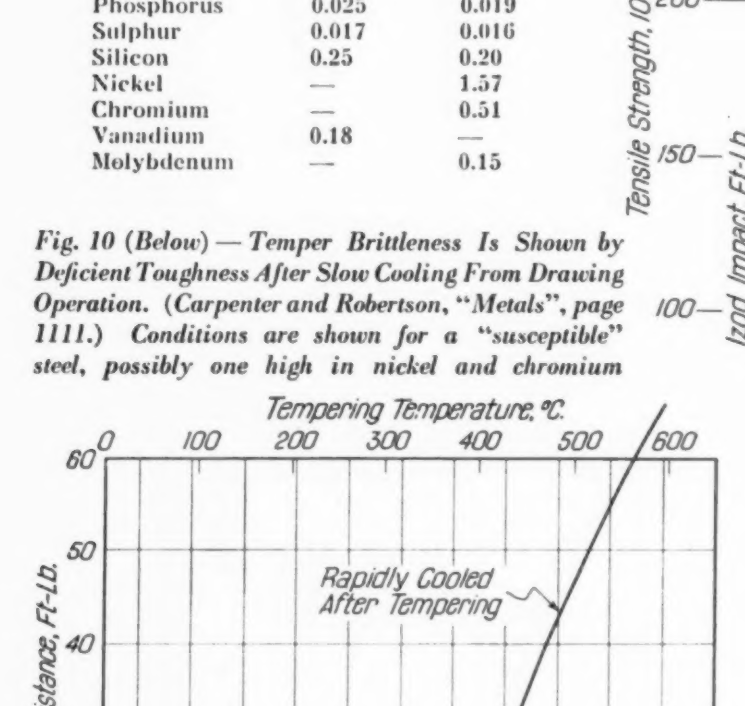


Fig. 10 (Below) — Temper Brittleness Is Shown by Deficient Toughness After Slow Cooling From Drawing Operation. (Carpenter and Robertson, "Metals", page 1111.) Conditions are shown for a "susceptible" steel, possibly one high in nickel and chromium



values should not be used unless directional properties are actually utilized in design. Specimens taken transverse to the rolling direction of straightaway rolled plate will approach or fall below the lower dotted line. Longitudinal specimens from forged bars will approach or exceed the values for longitudinal specimens on straightaway rolled plate, the actual value depending upon the degree of forging reduction.

It is necessary that specimens for these tests be taken from full-sized sections, heat treated according to industrial practice. All too often properties obtained by specially heat treating small test specimens are used to represent large parts which are never fully hardened during heat treatment.

How Much Toughness Is Needed?

H. W. Gillett's admonishment* that a high degree of toughness is not required for many supposedly severe applications, and his examples of satisfactory cast iron crankshafts which have very low notched-bar impact, must be approvingly cited. For all parts designed and fabricated so that there are no sharp changes in section or imperfections to cause severe stress concentrations very little toughness is required in machine parts.

On the other hand brittle failures occur in many parts never stressed beyond the

*"An Engineering Approach to the Selection, Evaluation, and Specification of Metallic Materials", Penton Publishing Co., page 61.

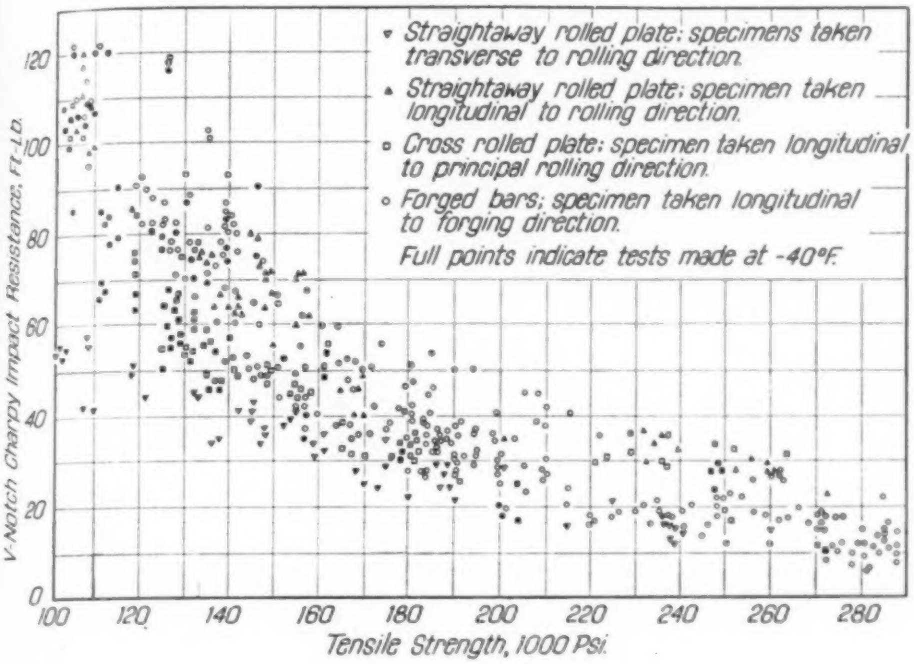


Fig. 11 — Correlation of Strength and Impact Values for Steels Not Subjected to Embrittlement During Tempering

design strength because the steel is insufficiently tough under the conditions of service. Likewise, parts subjected to shock loading usually require a high degree of toughness. The assurance that he can get steel that is really tough may allow the designer to reduce his factor of safety and make large savings in weight. This has actually been done in some ordnance items that gave excellent service during the last war.

The toughness values indicated by the chart represent the highest obtainable when the best metallurgical principles are observed in selection and heat treatment of reasonably clean steel tested in the prescribed manner. It would be very expensive and entirely impractical to require the maximum degree of toughness in all applications. The only basis by which the minimum toughness required for a given application can be judged is the results of service performance, or of truly simulative service testing.

Structural grade steels of less than 100,000 psi. tensile strength (below the limits of Fig. 12) may have maximum obtainable notched-bar impact values of well over 100 ft-lb., but the minimum required impact value for many applications of such steels may be as low as 10 ft-lb. at −40° F. Since differences among Charpy impact values, each of which is greater than 100 ft-lb., have little practical significance, the figure of 100 ft-lb. may be taken as an optimum for low strength steels.

In conclusion, it is the authors' belief, derived from extensive testing of ordnance components and an examination of literature germaine to the subject, that a merit rating or P value that depends largely on the reduction of area figure from the ordinary tensile test is not a reliable criterion of toughness, or ability of a metal part to absorb energy before fracture. This is better established by a Charpy V-notch impact test, made when the specimen is at −40° F. This value should be higher for steels of moderate tensile strength than for steels of higher hardness and strength, and a workable relation between these two values is plotted in Fig. 12.

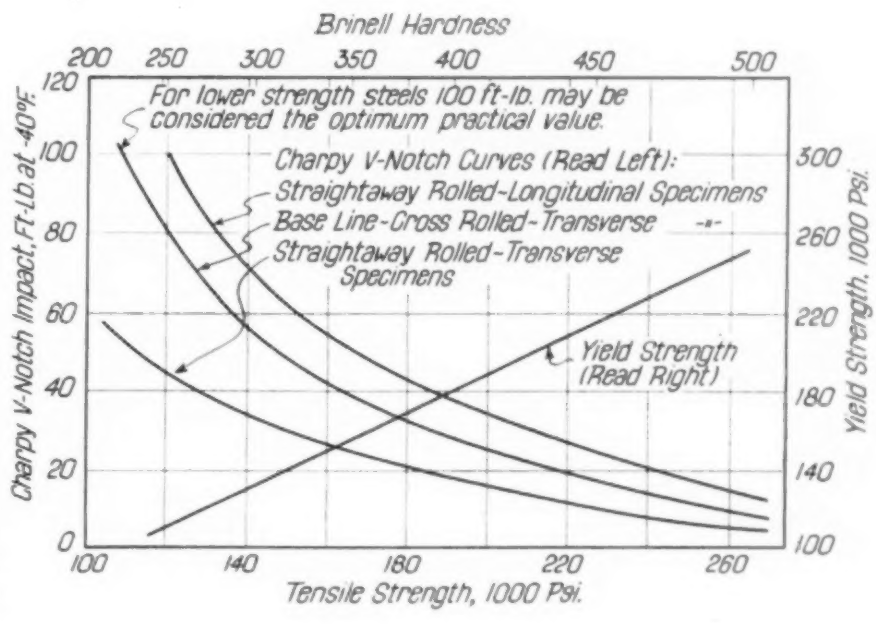


Fig. 12 — Relationship of Yield Strength, Charpy V-Notch Impact Resistance, Hardness, and Tensile Strength of Properly Heat Treated and Reasonably Clean Steels

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Random Notes on Chinese Steel Industry

As a member of a group of engineers sent to Chungking in the spring of 1945 to help the Chinese government increase the production of necessary articles for both civilians and the army, I was able to visit practically all the steel plants in "free China" (that portion not then occupied by Japanese troops), and The Editor thinks that some of my recollections will be of rather general interest.

The largest blast furnace is of 100-ton capacity but averages about 60 tons of pig iron a day. There are about 27 blast furnaces of smaller size down to 20 tons rating. One of the largest blast furnaces I have seen has a rated capacity of 63 tons per 24 hr. (based on American performance) but has been able to produce not more than 30 tons when operating. It is fairly well designed, being equipped with a skip hoist and four stoves — it is notable because most furnaces of all sorts are hand charged. An interesting feature was the construction of the cold blast mains — they were made from old oil or gasoline barrels!

There are about five openhearth furnaces, the largest being a 15-ton furnace, gas producer fired, with water cooled doors and frames; this one is the most modern looking and well designed furnace here, but the auxiliaries are so poor that normal production by American standards can never be reached.

There are 12 electric arc furnaces, some basic and some acid lined; the largest has 3 tons capacity. There are also a few high frequency induction furnaces of various sizes, from 50 to 1000 lb. There are also about a dozen acid bessemer converters — all very small, all side blown.

There are no blooming mills in free China. Even the bar mills start with small ingots and either roll them into finished product or into small billets for further conversion on the same mill. Several mills are two-high, the piece being passed over the top roll, or dummied between passes. Each plant tries to roll everything instead of rolling that for which the mill might be best fitted. Practically every mill I have visited has been trying to roll light rails, and the results have not always been completely satisfactory. Amount rolled per hour seldom exceeds one ton per mill, and the monthly production on some mills does not exceed 50 tons!

Most of the mills are very much underpowered. Many of them are driven by salvaged marine engines to which they have added flywheels (which certainly are required) but the Chinese never bother to install governors. Most of the rolling mills are without shears, the finished product being cut to length with chisel and sledge. The engraving on page 470 shows a stamping press operated by man power — quite the usual thing. There are very few straightening machines of any type. One of the members of our commission found a roller straightening machine for rounds (made in Germany) set up in a machine shop; the Chinese thought it was some kind of a machine tool.

Raw Materials

One of the most serious handicaps to production from such equipment as was operating was that all the raw materials are of very poor quality.

In Yunnan province, down south, near "the hump" there are ore deposits of good physical and chemical quality, but the available iron ore in the Chungking area is almost all high in phosphorus. Its physical properties could be ranked "fair" to "good". It was the general practice in ore mining to throw aside everything under 1-in. size (which

in the United States would be considered excellent raw material) and ship only lumps which can be smelted in the blast furnaces even with the very low wind pressures created by the available blowing engines (ordinarily around 1.7 psi.). Since the ore fines amounted to as much as 25% of the product of the mine, its rejection added seriously to the mining problem. We urged trials of this smaller size ore, and in one plant where fairly good blowing equipment was available successful results were obtained.

There is only one large coal mine in the Chungking area, but there are many scattered small ones. Much of the coal is high in sulphur, and almost all of it is low in volatile matter and very high in ash (15 to 22%). It is mined entirely by hand, the average size is very fine and the moisture content up to 4%. Very little of the coal mined is washed and then only by crude and inefficient methods. We endeavored to assist the Chinese in planning and installing some simple improvements for coal washing, and the initial trials of this equipment have shown very promising results in reducing the ash and making a coal better suited for coking.

Coke is made from this coal by burning in open rectangular pits. The character of the coal is such that the type of beehive oven which was so successfully used in the United States is not suitable. Because of its high ash, high moisture and low B.t.u., much of the coal has to be burned in order to produce some residue of coke; the actual yield of coke is about one-third of the coal charged into the coking pits.

The refractories available to the Chinese iron and steel industry are generally inferior in quality. Some materials are wholly lacking — there is, for example, no magnesite or chrome oxide. Dolomite of variable quality must be relied on for basic linings. The furnace men are afraid to make low carbon heats because of the damage it will likely do to their furnace. There is no mica schist available and bessemer converters must be lined with native sandstone. Most of the steel plants make their own brick, a fact which has perhaps somewhat retarded the development which might have resulted if there were a separate refractory industry.

Transportation

In free China railroads are practically nonexistent. The highway system is a very limited one, motor fuel is scarce, and truck maintenance a difficult matter; what roads there are are so poor I think the Army got the ideas for tank traps and proving grounds from them. It is a common thing to use up half the day in going from the city out to a mill only 10 miles distant. For these reasons the raw materials required for iron and steel manufacture must be carried on the backs of laborers or transported in river junks and sampans which have no mechanical power, but are propelled by oars or towed by men walking along the shores of the river, each man equipped with a harness attached to the tow rope. It is almost impossible to realize that men can be found to perform such arduous labor. The river at Chungking has a rise and fall of approximately 110 ft., and during high water, transportation by river is at a standstill.

Once at the steel plants the transportation problem still exists, for departments are widely scattered — it is said that this is so it is harder to bomb a plant out completely. At any rate, one plant has part of its operations on one side of the big river, and the rest on the other. On one side are some inclines; on the other the material ferried over is carried up about 600 shallow steps.

Pouring First Hot Metal Into 10-Ton Openhearth in Free China

There are no industrial railroads. Wheelbarrows, even, are very scarce. Animals are very scarce; the human is the beast of burden. Practically all transportation throughout the works is done by the workmen carrying the material in two baskets suspended from a stick or beam resting on their shoulders; the usual load is about 150 lb. (Try and carry that, yourself!) In some plants they are paid by piecework, possibly the Chinese equivalent of so much per ton-mile.

Steelmaking

As indicated above, it is not easy to make soft, low phosphorus steel in small openhearths lined with inferior refractories, and fired with inferior fuel. Heats are usually so small that temperature losses during tapping and teeming cause a lot of reversion of phosphorus. Alloys are very, very scarce, and the costs are astonishing. An additional handicap is the lack of low carbon ferros. Their ferromanganese runs 40% Mn and 7 or 8% C; after a second refining in an electric furnace the manganese goes up to 60% but the carbon comes down only to 5%. Try to make a low carbon heat for telephone wire with such materials.

However, it was fun to see the Chinese deoxidize bessemer steel in the ladle by throwing in a piece of a crashed Jap airplane.

Laboratory Facilities

Steel plants were found to be very poorly equipped with instruments. There were few pyrometers and gages. Often we found complicated recorder-pyrometers out of order, and they could not be repaired because there were no special parts, or because no one had enough skill at instrument making.

Chemical laboratories are few in number and deficient in equipment and chemicals. This resulted in a lack of analytical information for plant control with an unfavorable effect upon production and the quality of product.

While there were only five or six metallographic laboratories in free China, this did not appear much out of line with the needs. The individual laboratories were equipped with polishing wheels and microscopes which were fairly adequate even though not of the most modern type. The operation of these laboratories was hindered, however, by a serious shortage of abrasive supplies for polishing specimens. This seemed to be symptomatic. Even in the best of the laboratories there always seemed to be something important missing that prevented them from putting what they had to good use.

We surveyed the physical testing equipment of universities, government research bureaus, arsenals, and steel plants, and found these agencies to be irregularly and inadequately equipped. This was particularly true of the steel plants, some of which did not have a single instrument of any kind for physical testing and therefore unable to apply any kind of quality control over their product except rule of thumb to meet speci-

This Stamping Press Is Being Used for Blanking Out Shovels. The workers on the lower level place the heated sheet between the dies, which are brought together by a large screw connected with a horizontal wheel, operated by coolie power. (*Courtesy* U.S. Steel News)

fication requirements. To determine even so simple a thing as Brinell hardness the best they could do was to carry a few samples to an arsenal or a university laboratory.

Safety Last

Manifestations of cheap human life are perhaps the most difficult thing for an American engineer to get adjusted to in China. Even though skilled labor is very scarce and hard to find, "safety first" is absolutely unknown. Workmen are not provided with safety glasses. There are no guards placed on grinding wheels, gears or any other equipment. Men ride the crane loads wherever there are cranes in the various buildings. Women, some carrying babies and children, visit in the plants. Hot ingots, blooms, and billets are wheeled to the table rolls of the mills. None of the workmen have gloves, some of them have homemade mittens, and some use rags. They do not know what a safety shoe is — most of them wear sandals, a few have something that looks like a low cut tennis shoe, and some work barefooted. Some of the men work on the furnaces with only a pair of shorts and sandals on their bodies.

Comparative Prices in Chinese Dollars

	1937	June 1945
Steel, per metric ton	$200	$240,000 to $300,000
Copper, per metric ton	$ 50	$5,000,000 black market
Coal, per metric ton	$8–$10	$10,000 to 15,000 official
		$30,000 to 40,000 black market
Coke (ash under 20%), per metric ton		$ 50,000
Charcoal pig iron, per metric ton		$200,000
Pig iron, per metric ton		$300,000
Rice, per picul (133 lb.)	$ 8	$16,000
U.S. Dollar, market	$2.50	$ 1,400
Official		$ 20
Missionary		$ 40
Overseas Chinese		$ 100
Monthly wages; unskilled labor	$ 12	$15,000 to 18,000
Clerk	$100	$30,000
Bank clerk	$100	$50,000

Production Problems

In addition to the above mentioned handicaps, there is also the matter of costs, partially indicated in the table above. We American advisers could not do much with the economics, but technical suggestions made for improvement were eagerly received and quickly acted upon. The Chinese managers were usually keen to expanding a single suggestion into a considerably enlarged field. For example, in one plant we called attention to the high percentage of high phosphorus heats of open-hearth steel and suggested ways in which phosphorus reversions could be prevented. The management then found that, in addition to reversion of phosphorus from the slag to the steel, phosphorus was actually being added, due to the fact that the limestone was contaminated with calcium phosphate, and proceeded vigorously to correct this state of affairs.

Mills shut down for an hour in the middle of the turn for the men to eat lunch. Most of the men go home, as they live on company property. In order to get them to do any work at night, workmen must be paid double time and furnished with a midnight meal.

Other reasons which might be advanced for sporadic operations (as low as two turns a week) are inadequacy of budget or operating capital, lack of demand, shortage of labor either skilled or unskilled, shortage of raw materials, shortage of power, and excessive time required for repairs. While living conditions are terrible, the people work incredibly hard, mind their own business, and smile easily. The greatest difficulty seems to be that the ordinary citizen believes that "what was good enough for grandpa (and his grandpa) is good enough for me". Sometimes it looks to me that if there were a harder way to do a thing, that is the way the Chinese would do it.

Even though statistics on capacity and production are entirely lacking, it is obvious that overall production in free China has been far below the total capacity of the separate units. This has been due to a large number of handicaps, such as poor marketing, limited types of mills and finishing equipment (and even unnecessary duplication of certain types). Lack of raw materials and especially power also tends to hold down production. None of the plants work around the clock, very few of them even work every day shift. There is also a lack of diversified industries to utilize the available semi-finished products and a comparatively low demand for iron and steel products by civilians. (Civilians must get along without; iron and steel costs them about 20 times — 20 times in the value of an hour of labor — what it costs an American.) There are no plants producing pipe or sheets, which are so vital in wartime.

In all fairness, however, it must be realized that China's wartime iron and steel industry has been working in a completely blockaded area and struggling with extraordinarily difficult economic conditions with a limited background of experience and with only rudimentary facilities. I hope we Americans would have done so well had we been in their unfortunate position. They were then entering the ninth year of war.

By R. David Thomas, Jr.
Vice-President and Director of Research and Engineering
Arcos Corp., Philadelphia

Crack Sensitivity of Chromium-Nickel Stainless Weld Metal

STAINLESS arc welding electrodes have found a wide variety of applications in other fields besides the mere welding of stainless steel parts because of the great ductility of the weld metal. An outstanding example is its extensive wartime use for making joints in armor on warships and combat tanks. But ductility or toughness of a welded joint presupposes sound metal, and the existence of cracks in a weld will nullify the benefits derived from the use of these alloys. For this reason, it is worth while to consider the sensitivity of various stainless alloys to weld metal cracks.

A great deal of attention has been focused on this problem during the past six years. Much of the information is inconclusive, but as a result of several carefully conducted investigations and considerable field experience, some good hypotheses have been developed. This article presents a general summary of experience with many grades of high chromium-nickel alloys.

Despite all that has been learned, weld metal cracking is occasionally encountered which has no reasonable explanation. There is still more work to be done and more data to collect, but in the meantime, fabricators of stainless equipment should be informed about the experience which is now available. A well-founded reputation should not be jeopardized by ignorance of some of the known factors which make stainless weld metal susceptible to cracks.

Appearance of Cracking — Two types of weld metal cracks are encountered in stainless welding. The more common are longitudinal bead cracks which often extend from crater cracks, root notches or entrapped slag. These cracks are distinguished from the less common, but more exasperating "check" cracks, which are generally very fine and may extend in any direction. Both types are shown in Fig. 1 to 3. Longitudinal cracks are readily picked up by visual inspection of the weld bead; if this type of cracking is suspected, but no cracks show on the weld bead surface, radiographic inspection is used. Crater cracks usually reach the surface and are therefore detected by careful visual inspection. Check cracks are visible on the surface only in extreme cases.

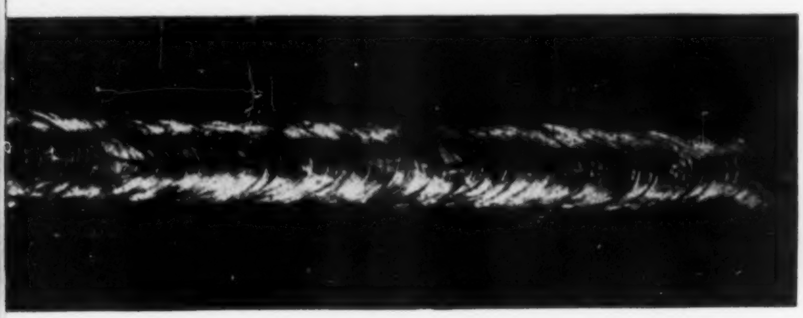



Fig. 1 — Longitudinal Cracks in Root Passes With 25-20 Electrodes. At left: Titania coated electrode deposits a concave bead contour which is more susceptible to cracks. At right: Lime coated electrode deposits a flat bead which is more resistant to cracks

Fig. 2 — Typical Crater Crack in a 25-20 Deposit

Even the use of X-rays or gamma rays may fail to reveal the extremely fine cracks. To show evidence of these fine cracks requires a test which stretches a substantial amount of the weld beyond the yield strength. Thus, the all-weld-metal tension specimen which is the usual test for quality control of stainless electrodes is ideally suited for demonstrating the existence of fine cracks (see Fig. 4, page 476).

Factors Affecting Cracks

Stresses — Cracks in weld metal result from stresses caused by shrinkage, restraint, and notches in exactly the same manner as cracks which occur in ingots or other castings. The coefficient of contraction and the ease of plastic deformation are fundamental properties of the alloy which determine the amount of stress on the weld metal. The joint design, the pass sequence, the freedom from notches and the rigidity of the weldment are mechanical factors affecting weld metal cracking. These mechanical factors are within the control of the designer, the engineer, and the welding operator. The other factors require the attention of the metallurgist.

Microstructure — Stainless electrodes of the chromium-nickel alloys are generally termed "austenitic", meaning that the austenite solid solution is predominant in the microstructure. In any study of cracking it is worth while to distinguish between weld metals whose structure is completely austenitic and those which have some ferrite present in an austenitic matrix. The 25-20 Cr-Ni electrodes deposit a fully austenitic weld metal structure, and the 19-9 Cr-Ni electrodes deposit a partially ferritic structure. Strangely enough, among the common stainless alloy electrodes, cracking is always more prevalent in the fully austenitic weld metals than in the partially ferritic weld metals, despite the commonly accepted idea that austenitic solid solutions are very ductile. The reason for this will become apparent from a study of the microstructure (below).

Recognizing this fact, the metallurgist immediately becomes aware of the effect of the various alloying elements on the microstructure. This information can be found in the literature for all of the common elements. The following formula proposed by F. K. Bloom of Rustless Iron and Steel Division has been found very helpful for determining the microstructure of weld metals:

$$Ni = \frac{(Cr + 2Mo - 16)^2}{12} - \frac{Mn}{2} + 30(0.10 - C) + 11$$

If the percentage of nickel in an alloy under appraisal is less than the value indicated by the formula, the structure will probably be partially ferritic; if more, the structure will probably be entirely austenitic. The greater the deficiency of nickel the more ferrite will be found in the weld metal.

The appearance of the two microstructures is shown in Fig. 5 and 6. The ferrite constituent in Fig. 6 is harder and stronger than the austenite matrix, and its presence in a finely dispersed dendritic pattern is a deterrent either to the

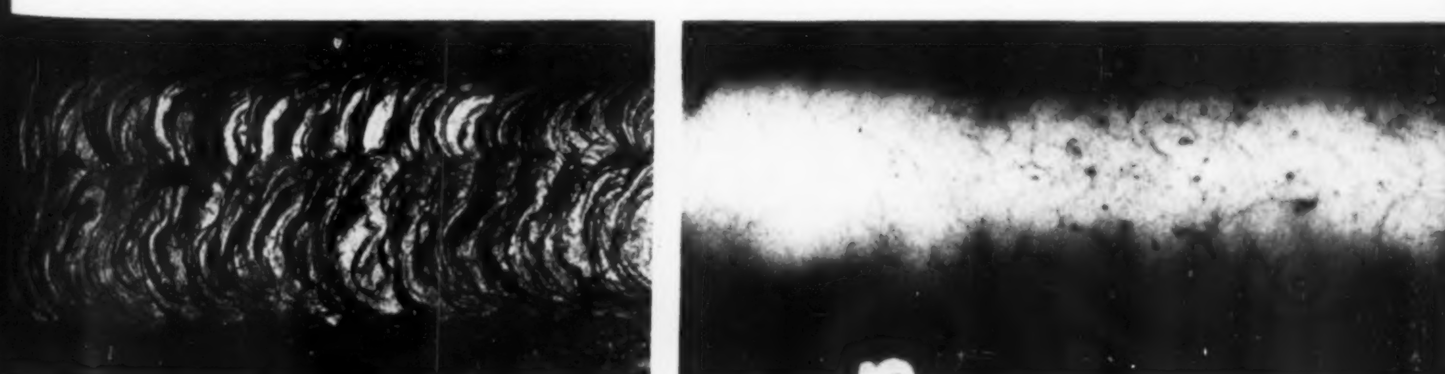


Fig. 3 — An Extreme Case of Check Cracking Encountered in a 13 Cr, 60 Ni Alloy. At left: Its surface appearance. At right: X-ray photograph of the same specimen

formation of cracks or to the growth of the cracks once formed. There is evidence that the presence of ferrite during solidification is an additional deterrent to crack formation. Consequently it has long been recognized that partially ferritic weld metals are less crack sensitive than fully austenitic weld metals.

The formula given above indicates the relative importance of the various elements in their tendency to form ferrite. Additions of manganese and carbon, like additions of nickel, decrease the ferrite formation, manganese having only half the potency of nickel and carbon 30 times the potency of nickel. Chromium and molybdenum increase the tendency for ferrite formation, molybdenum being twice as effective as chromium. This relationship assisted the development of the 19-9 analysis, modified with manganese, used so successfully for armor electrodes, and indicated the value of using small amounts of molybdenum to adjust the structure to be less sensitive to weld metal cracks.

The presence of ferrite in the weld metal structure of an armor electrode is demonstrated by applying the equation to a weld metal containing 0.12% C, 4.0% Mn, 19.0% Cr, 9.0% Ni and 0.75% Mo:

$$\begin{aligned} Ni &= \frac{(19.0+2\times 0.75-16)^2}{12} - \frac{4.0}{2} \\ &\quad + 30\ (0.10-0.12)+11 \\ &= 1.7-2.0-0.6+11 \\ &= 10.1 \end{aligned}$$

If the actual nickel were higher than the 10.1% computed by the formula, the structure would probably contain no ferrite.

Molybdenum appears to overcome tendencies toward cracking, not only by forming ferrite in the weld metal, but also by strengthening the austenite. The acceptance of the 19-9 analysis, modified with molybdenum, for armor electrodes is attributed to its great resistance to cracking during fabrication. The weld metal structure has a relatively high percentage of ferrite in a strong austenite matrix. Even without ferrite, however, the completely austenitic chromium-nickel weld metals are less susceptible to cracks when they contain some molybdenum than similar alloys with none of this element. This is illustrated by the relative position of 18-13 Mo (Type 316) weld metal in Table I, for it is the least sensitive of the fully austenitic alloys.

Columbium, like molybdenum, tends to form ferrite, but unlike molybdenum, it makes the austenite crystal more susceptible to cracks. In the common 19-9 alloy, stabilized against intergranular corrosion with columbium, best ductility and corrosion resistance require a balance between the ferrite-forming tendency of columbium and additions of nickel. The net effect is an alloy with about the same amount of ferrite, but because of the influence of the columbium on the austenite crystal, the crack sensitivity is more pronounced. Likewise, additions of columbium to fully austenitic alloys, such as 25-20, make them more susceptible to cracks. This influence extends to alloys which combine both columbium and molybdenum in a fully austenitic weld metal; the result is an extreme sensitivity to weld metal cracks. If the composition is adjusted to permit the formation of a small amount of ferrite, the cracking tendency is greatly reduced.

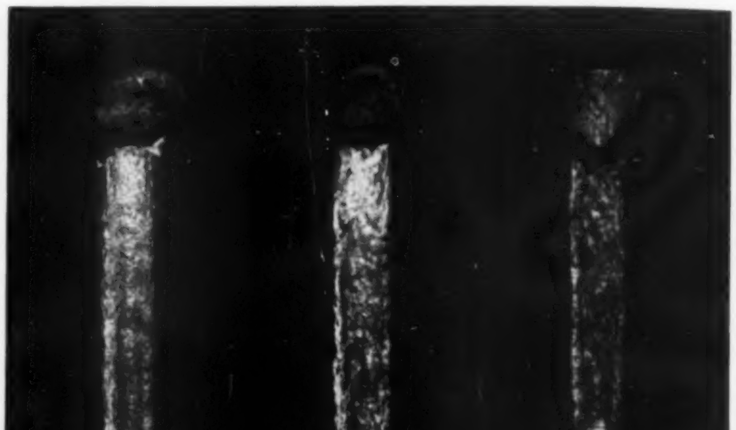


Fig. 4 — Standard 0.505-In. Tension Test Piece, All-Weld-Metal, Showing Surface Check Cracks on the Crack Sensitive Alloy. At left: 19-9, partially ferritic weld metal, highly resistant to cracks. Middle: 25-20 fully austenitic weld metal free from cracks. Right: A lot of 25-20 weld metal having poor ductility as a result of cracks

In addition to its effect in making the structure fully austenitic, nickel appears to increase the crack susceptibility of chromium-nickel alloys. In general, the greater the excess of nickel over the

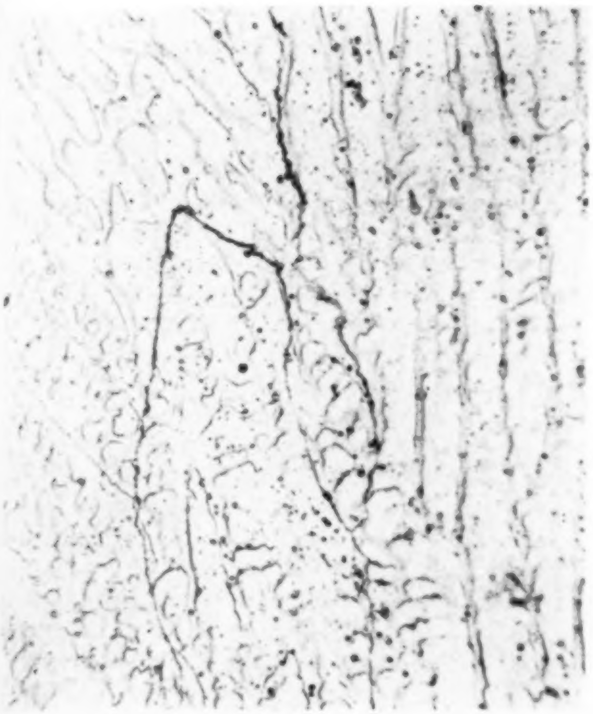


Fig. 5 — Microstructure of Fully Austenitic Weld Metal (25-20), More Susceptible to Weld Cracks. Both Fig. 5 and 6 have been given an electrolytic etch in 10% oxalic acid. 500 diameters magnification

amount indicated by the formula given above, the more crack sensitive the alloy becomes.

Experience collected in the field of stainless welding has led to a recognition of the relative crack susceptibility of the more common stainless weld metals. The relative position shown in Table I is based on this general experience rather than on any one type of cracking test.

Residual elements are considered to be all those present in amounts less than 0.20% each, including carbon, sulphur, and phosphorus, although these are inseparable to the production of stainless as well as the common steels. Other elements commonly thought of as "residual" are nitrogen, lead, zinc, tin, titanium, vanadium, zirconium, copper, aluminum and calcium. The influence of all these elements is not completely understood, but each has been the subject of considerable research.

The influence of the more common elements, carbon, sulphur, and phosphorus, has received much attention in recent years. Carbon was immediately suspected of causing cracks because carbide precipitation was observed in the vicinity of fine fissures in the weld metal. On the other hand, early work on 25-20 had demonstrated that when carbon was low the susceptibility to cracking increased; for this reason the Navy specification for 25-20 weld metal places 0.09% as a lower limit for carbon. Sulphur has been found to have little influence until the amounts are away above common specification limits. The tolerance for phosphorus is extremely limited in fully austenitic weld metals, and depends somewhat on the other alloying elements; even below the usual specification of 0.030% max., phosphorus may influence crack susceptibility depending on the balance of other elements.

The net result of most of the recent research on the uncommon residual elements is to show that their effect is insignificant within the tolerances commonly encountered in stainless weld metal. However, part of the inconsistencies between laboratory tests and practical experience may be due to combinations of residual elements which occur in practice even though, taken individually, all elements are within harmless limits. The uncommon residual elements may easily be responsible in some of the rare cases of cracking which appear to have no other reasonable explanation.

Electrode Coating — The influence of the flux covering is so varied that it is necessary to subdivide it into separate components, and to comment briefly on each.

It is difficult to say to what extent bead cracks can be explained by faulty arc action of the elec-

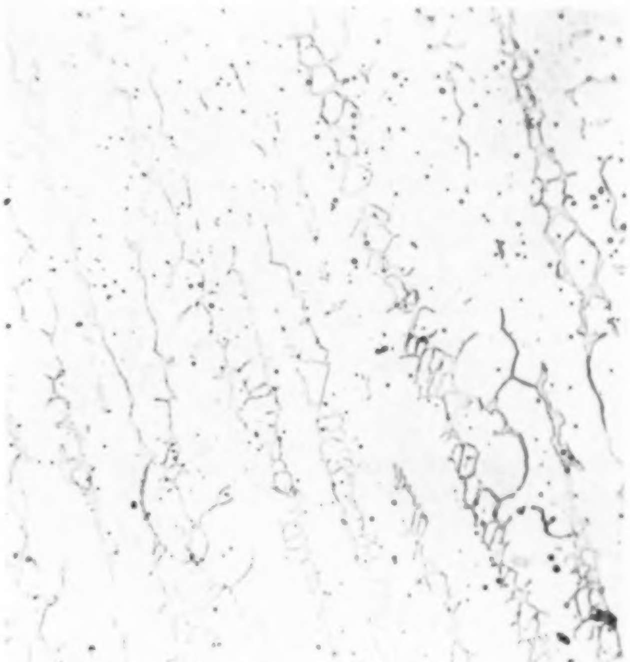


Fig. 6 — Microstructure of 19-9 Weld Metal, Showing Ferrite in Austenite, a Structure More Resistant to Cracks Than Single Phase Austenite

trode, but it is reasonable to suppose that an electrode which pinches out readily or which shows abnormal arc blow and "fingernailing" might contribute to cracks in the weld metal.* Similarly an electrode which deposits too much slag, or deposits a slag which has a tendency to be entrapped, would certainly increase the tendency toward weld bead cracks.

Table I — Common Stainless Weld Metals Arranged in Order of Increasing Crack Susceptibility

Type No.	Popular Name	Comments
301	16-7	Least susceptible; has relatively high ferrite content.
308	19-9	Has medium ferrite content.
347	19-9Cb	The increase in ferrite by Cb is usually balanced by Ni additions. Cb increases the crack susceptibility.
316	18-13Mo	Sufficient nickel is added to counterbalance the ferrite-forming tendency of Mo. This is the least crack sensitive of the fully austenitic alloys.
309	25-12	Cr is usually about 23% and Ni 14%, giving a fully austenitic structure.
309 + Cb	25-12Cb	Cb tends to make the structure partially ferritic, which counterbalances cracking tendency otherwise caused by it.
310	25-20	Fully austenitic alloy, and therefore more sensitive than those above.
310 + Cb	25-20Cb	Cb cannot form ferrite in this alloy, and therefore makes the alloy more sensitive than the straight 25-20.
330	15-35	Fully austenitic alloys having more Ni than Cr are more sensitive to cracks than those with more Cr than Ni.

Root bead cracking is more commonly encountered in metal from electrodes which deposit a concave bead contour, because of the thin section which must take all of the shrinkage stress (see Fig. 1 at left). Conversely, root beads which give a convex surface have greater resistance to cracks because of their greater cross section. If the contour is exaggerated, however, the cleaning of slag along the line of fusion between weld and plate becomes difficult, and residual slag pockets which are not completely removed may start cracks in subsequent beads. The weld penetration may affect cracking particularly if the molten metal is diluted with mild steel or low alloy steel being welded. These matters are all influenced by the type of electrode coating.

As well as the above-mentioned characteristics, the metallurgy of the weld metal may be altered by the type of electrode coating. Coatings containing titanium oxide tend to make the weld metal more crack susceptible than the coatings containing no titania. A number of explanations for this tendency have been offered, but since there is no general agreement, any statement might well wait.

The influence of the electrode coating is mainly one of degree — that is, if other conditions favor cracking, the type of coating may increase or decrease the amount of cracking. For example, an alloy which is notably crack sensitive when deposited by a titania type of electrode may become freer from cracks by eliminating the titania from the coating. On the other hand a change in coating may introduce electrical variables which may not improve the situation. Usually, it is better practice to attack the other factors which cause cracking before considering the complex nature of the electrode coatings and their effect on the problem.

Dilution — The use of stainless electrodes to weld many different types of metals, often unrelated to the analysis of the weld metal, raises the problem of dilution and its effect on crack sensitivity. In welding dissimilar metals, the alloy content of the base metal alters the composition of the weld metal, and sometimes the crack sensitivity of the resulting mixture is greater than that of the undiluted weld metal. This factor must be kept in mind in all welding operations involving dissimilar alloys.

Control of Cracking

Welds which are certain to be free from cracks require the attention of the welder, the welding engineer, the metallurgist, the designer, and the electrode manufacturer. The degree of attention that is necessary depends on the susceptibility of the alloy and the design conditions which may produce cracks. For instance, if a fully austenitic weld metal is to be used on a job involving heavy sections imposing high stress on the weld metal during welding, the welder must be careful to make clean deposits with root beads of adequate thickness and carefully filled craters; the welding engineer must design the joints to provide minimum stress during welding; the metallurgist must specify control tests on the welds to assure satisfactory materials; and the

*The term "fingernailing" is used to describe the failure of the coating to melt uniformly on all sides; one side of the coating extends well beyond the melting core wire preventing the proper manipulation of the electrode.

electrode manufacturer must supply electrodes which will meet the required conditions.

Many types of alloys are not sensitive to cracking and many welding applications do not impose high stresses on the weld metal during cooling. For these conditions rigid control procedures will become cumbersome and unnecessary. Necessary control procedures must be determined by experience, but lacking this, it is generally more economical to set up a rather precise control and avoid defects rather than analyze the defect after it is found.

Summary

The reputation of stainless electrodes to weld a wide variety of materials and to give high quality weld metal for corrosion and heat resisting service must be protected by an understanding of the factors which may cause cracks in the various types.

Weld metal cracks occur at elevated temperatures and are caused by shrinkage stresses developed on solidification and cooling. The amount of shrinkage is determined by the amount of metal deposited and its coefficient of contraction.

Stainless weld metal has a microstructure essentially of austenite, but certain analyses contain small quantities of ferrite. The presence of ferrite is a deterrent to the formation of cracks; that is to say, partially ferritic weld metals are less crack susceptible than the fully austenitic compositions.

Certain residual elements greatly increase the susceptibility to weld metal cracks, but the amount of residual elements commonly found in stainless welds has little effect.

When all other things are equal, the titania type coatings are more likely to produce cracks in susceptible alloys than the lime type coating.

Cracks in stainless weld metal may arise from changes in composition of the weld metal as a result of dilution by a dissimilar base metal.

In setting up control procedures to assure the absence of cracks in stainless welding, engineers, metallurgists, and designers should recognize the factors which cause cracking and make provisions to control them within safe limits.

Foaming of Bearing Metal During Casting

By E. A. Wolfenden
Inspector, Norfolk & Western Ry. Co., Roanoke, Va.

WE RECEIVED recently a shipment of white metal alloy to be used for the lining of bearings. Since this material is purchased to chemical specification alone, representative samples are secured from pigs selected at random from the order. For this lot the analytical results were unusually uniform and conformed to the specification, as will be noted in the table. Fractured pigs showed a fine grain, clean metal with no segregation, oxidation or inclusions.

Metal from this shipment was added to an electrically heated pot containing approximately 3500 lb. of the same type of alloy until the estimated concentration of new metal to the old was 15%. At this point the metal showed a tendency to froth while being poured into the bearing backs. This frothing condition became progressively worse with increase in concentration of the new metal until it became impossible to cast a sound lining in the bearing.

Analyses of Bearing Metal and Froth

Element	Check Analysis	Specification	Froth
Tin	3.50%	3 to 5%	5.0%
Lead	86.06	84 to 89	80.4
Antimony	10.32	8 to 11	9.44
Copper	0.48	0.5 max.	4.83
Iron	0.20	—	0.33
Arsenic	trace	0.2 max.	trace
Zinc	none	1.0 max.	none
Alkaline earths	none	—	none
Aluminum	none	—	none

Average analysis of the froth which appeared on the pot as a wet dross and on the bearing lining as a very spongy, gray metal is also shown in the table. Analysis of the froth was made on skimmings from a 3500-lb. melt, made in a clean pot, of all new metal. Approximately 50 lb. of froth was skimmed from the pot immediately after the

metal had melted. Stirring of the remaining metal, however, produced more frothy dross.

Attempts were made to eliminate the frothing by treating the metal in the pot. Sulphur, ammonium chloride, rosin, old leather and green pine poles were used separately and in various combinations. None of these treatments appreciably diminished the trouble. Dilution of the metal by the addition of tin up to 9% total content and of antimony to 14% was tried with no improvement.

It was found that by increasing the temperature from the normal pouring temperature of 625° F. to slightly above 900° F. the metal could be poured without frothing; however, it was practically impossible to retain the lining metal in the backs at this temperature.

The literature at my disposal is limited; references pertaining to the white metal bearing alloys and their idiosyncrasies are even rarer. However, a note was found which indicated that the cause of the frothing may be due to the copper in the metal. Analysis showed copper concentrated in the froth, but we had no way of reducing the amount of copper in the original metal; likewise the latter's copper content was within specification limits, and similar trouble had not arisen with similar metal. So the problem of eliminating the frothing condition still remained. Accordingly a letter describing the trouble and containing a plea for help was sent to several metallurgists in bearing metal industries. Before the replies could be received and analyzed, and a satisfactory routine established, we had used most of the offending metal in the form of minor dilutions to satisfactory metal, never using more than 10% of it in any melt. However, it may be worth while to record the complete story for the enlightenment of others who may run into this trouble.

Summary of Expert Advice

While the replies received from the experts did not entirely agree as to the cause of the frothing or as to the methods for correction, the consensus can be summarized as follows:

The presence of copper, iron, or both, in a high lead alloy in amounts exceeding 0.5% may cause frothing due to the formation of high melting alloys of copper and tin (or iron and tin) which have a lower density than the high lead alloy and therefore appear at the surface as a dross or froth. In a high tin alloy these compounds are heavier or as heavy as the melt and therefore sink — or at least do not rise to the surface. Furthermore, either high lead or high tin alloys containing sizable amounts of copper or iron or both must be poured at a temperature exceeding 900° F. to prevent segregation.

It was also pointed out that arsenic in excess of 0.10% will cause foaming and blowholes in this type of alloy. No flux is known that will remove this impurity; the only way it can be reduced is by dilution with good metal. Reference to the analysis of this metal will indicate, however, that its arsenic content was too low for it to do harm. Copper was near the specification limit, however, and it might possibly be the culprit.

To remove the copper and iron from the lining metal, either new alloy pigs or contaminated scrap, it was recommended that the metal in the pot should be allowed to stand overnight at 500 to 550° F. In the morning, without disturbing the metal unduly, skim off the dross which has accumulated on the surface. While the metal is still at low temperature treat with flowers of sulphur, using approximately 1 lb. of sulphur for each 2 lb. of copper in the metal. (It may be necessary to make several additions of sulphur depending on the amount of copper present.)

The sulphur is preferably added by means of a stirring device which creates a vortex that pulls down into the metal the powdered sulphur thrown into it. If such a stirring device is not available, the sulphur can be introduced into the metal by lightly tamping it into a perforated cylinder open at the bottom end, and with a long rod welded to the closed upper end to act as a handle for stirring.

Stirring should continue for approximately 15 min., after which the dross should be skimmed off with a perforated ladle.

After the sulphur treatment, the metal should be heated to a temperature of 850 to 900° F., again skimmed to remove any dross and immediately treated by placing on the surface of the metal approximately ¼ lb. of ammonium chloride (sal ammoniac) for each 1000 lb. of metal. After the ammonium chloride has been added the heat should be cut off, the metal stirred for from 10 to 15 min. and all dross removed as before.

If, after the metal has cooled to its proper pouring temperature (625° F.), it still has a tendency to foam it will be necessary to cool it down to 500 to 550° F. and repeat the entire process as outlined above.

The procedure as outlined above was tried on a small pot of the foamy metal with satisfactory results. The reason why this particular lot of bearing metal, conforming to satisfactory specification, gave us trouble remains, however, a metallurgical mystery, since past shipments having analyses containing higher copper and iron had been used without trouble.

Correspondence

Antiquity of Lost-Wax Process

ENILOM, USONIA

To the Readers of METAL PROGRESS:

It seems to me that it's high time somebody set the record straight. About every hour on the hour somebody remarks that the "lost-wax" or investment method of casting is really quite new, having been invented by Prof. B. Cellini only 400 years ago. The latest one to offer this excuse for the low state of development of the method is Mr. Vennerholm in the July issue, page 80.

However, there is incontestable evidence to indicate that the lost-wax method is really an old one. Passing lightly over the several references which indicate that this technique was known in Periclean Athens (see, for example, "Life of Greece" by Will Durant) I wish to call your attention to the following remarks from "Hercules, My Shipmate", by Robert Graves, pages 206, 209. Orpheus is telling the story of Daedalus's life in Crete to Jason's men on the Argo during the search for the golden fleece:

> "Daedalus was remarkable for his ingenuity. Many astonishing inventions are credited to him, including the art of casting statues in solid bronze by the lost-wax method. It is even claimed that he made artificial wings which he could flap like a bird's, and so sustain himself in the air . . . .
>
> "Let no one believe the foolish fable that Icarus wore wings which Daedalus had attached to his shoulders with wax, and flew too near the sun so that the wax melted and he was drowned. The wings symbolize the swiftness of their ship; and the melting of the wax refers only to the ingenious method of casting bronze, which he invented."

Despite the obvious suggestion that Daedalus had some connection with the aircraft industry, there is no record of his having made turbo-supercharger buckets.

METALLURGICUS

$250,000 for Traveling Fellowships

LONDON, ENGLAND

To the Readers of METAL PROGRESS:

It is clearly recognized in Britain, in Governmental and industrial circles, that the intelligent application of scientific research to industrial technique is one of the most potent means of accelerating industrial recovery. Those who have come to grips with this problem, however, early find that there is not only a dearth of qualified scientists giving attention to the basic industries, such as coal, chemicals, metallurgy, but the executives in those industries are rarely able to make an informed decision on advanced technical and scientific projects put before them. There is in fact a danger that these two essential partners in industry, the executive and the scientist, may never be able to find common ground, no matter how hard they may try.

In order to break this vicious circle and also to integrate the scientist into the structure of industry The Mond Nickel Co., Ltd., is making available $250,000 for the provision of fellowships. Although the avowed object of the scheme is to attract technically qualified men into the metallurgical industry, the awards are not in any way to be restricted to metallurgists. A man who has graduated in physics, chemistry, engineering, or any other branch of science will be eligible, if his knowledge and ability are of a kind which can be usefully employed in the manifold ramifications of metallurgical industry.

Another interesting feature is that the fellowships are not intended, even primarily, to enable graduates of promise to continue research work, which is usually the purpose of more orthodox endowments. Increasing the quantity and quality of research does not, in itself, satisfy the requirements of industry. The company has, therefore, in providing the fellowships, made an effort to coordinate the benefits of research with the practical requirements of industry. This is to be achieved by giving the young scientist, who has completed his technical training, the opportunity of widening his outlook and experience for a year or so, before he takes up work with industry.

This period may be spent in Britain or abroad, and will be devoted to the study of industrial conditions and problems, with special reference to the application of research. The company wishes an applicant for a fellowship himself to suggest the actual subjects he should study. The intention is that, at the end of the year, when he starts work in industry, the man will have acquired, side by side with his technical qualifications, a general preview of the methods

Preliminary Report on Second Bikini Test

THE Evaluation Board of the Joint Chiefs of Staff (Messrs. Compton, Dewey and Farrell, Generals Stilwell and Brereton, Admirals Hoover and Ofstie) has reported to President Truman; from it the following is extracted:

"It is now possible to make some estimate of the radiological injuries which crews would have suffered had they been aboard Test A target vessels. Measurements of radiation intensity and a study of animals exposed in ships show that the initial flash of principal lethal radiations, which are gamma rays and neutrons, would have killed almost all personnel normally stationed aboard the ships centered around the air burst and many others at greater distances . . . It is clear that vessels within a mile of an atomic bomb air burst would eventually become inoperative due to casualties.

"The second explosion was of predicted violence and is estimated to have been at least as destructive as 20,000 tons of TNT . . . The diameter of the column of water [thrown up by the explosion] was about 2200 ft.; it rose to a height of about 5500 ft., and contained roughly 10,000,000 tons of water. Waves outside the water column were 30 to 100 ft. in height . . .

"The explosion produced intense radioactivity in the waters of the lagoon estimated to have been equivalent to many hundred tons of radium . . .

"In the case of the underwater explosion, the air-burst wave was far less intense and there was no heat wave of significance. Moreover, because of the absorption of neutrons and gamma rays by water, the lethal quality of the first flash of radiation was not of high order. But the second bomb threw large masses of highly radioactive water onto the decks and into the hulls of vessels. These contaminated ships became radioactive stoves and would have burned all living things aboard them with invisible and painless but deadly radiation.

"It is too soon to attempt an analysis of all of the implications of the Bikini tests. But it is not too soon to point to the necessity for immediate and intensive research into several unique problems posed by the atomic bomb. The poisoning of large volumes of water presents such a problem. Study must be given to procedures for protecting not only ships' crews but also the populations of cities against such radiological effects as were demonstrated in Bikini Lagoon."

The President's Civilian Evaluation Commission (Senator Hatch, chairman; Senator Saltonstall; Representatives Holifield and Andrews; Dr. Edward U. Condon, Dr. Karl T. Compton, Bradley Dewey, William S. Newell, and Fred Searls) has also rendered a preliminary report. Significant conclusions follow:

"We believe that interesting distinctions between the general results of the two explosions can even now be drawn without the risk of serious error. Both explosions sank several ships. The ships remaining afloat within the damage area appear to have been more seriously damaged by the aerial explosion than by the submarine explosion. The damage to ships in the first test might have been far greater if the bomb had exploded directly over the target ship, the Nevada.

"In the first test much of the personnel within the ships would have received fatal doses of neutrons and gamma rays from the first deadly flash. On the other hand, the deadly effects of *persistent* radioactivity would have been much more severe in the second test. Had the target array been manned, it seems clear that casualties and both physical and psychological injury to personnel would have been very great. Rescue and attention to casualties would be difficult and dangerous. Within 2000 yards of the explosion, ships would probably have been inoperative and a lapse of weeks might well ensue before relatively undamaged ships could again be used in combat.

"The second bomb caused a deluge of water loaded with deadly radioactive elements over an area that embraced 90% of the target array. All but a few of the target ships were drenched with radioactive sea water, and all within the zone of evident damage are *still unsafe* to board. It is estimated that the radioactivity dispersed in the water was equivalent to that from many hundred tons of radium. Such results might be as disastrous to the fleet as the results of the first test, although in part for different reasons. An enemy possessed of two or more bombs might well so dispose them as to create simultaneously the deadly features of both tests. Such tactics might dispose of a fleet for many months; for example, consider a Pearl Harbor attack on these lines.

"As was demonstrated by the terrible havoc wrought at Hiroshima and Nagasaki, the Bikini tests strongly indicate that future wars employing atomic bombs may well destroy nations and change present standards of civilization. To us who have witnessed the devastating effects of these tests, it is evident that if there is to be any security or safety in the world, war must be eliminated as a means of settling differences among nations."

and problems of industry, and that he will thus see, in the proper perspective, his own place in industry and the lines along which his work can contribute most effectively to its development.

There is a secondary object: It is hoped that a number of such scientifically trained men will find their way into executive positions. This is a most promising method of breaking the vicious circle, for it is only by the appointment of technical men, with the necessary broad outlook and

Views on Atomic Control

EARLY in July, Mr. Baruch, United States member, presented a definite plan for the establishment of an International Atomic Authority.* Since then some revealing statements have been made; quotations are from official communiques or from published texts of addresses.

At a meeting July 25 of Committee 2 of the United Nations Atomic Energy Commission, Mr. GROMYKO, Russian member, said: "The United States proposals in their present form cannot be accepted in any way by the Soviet Union either as a whole or in separate parts." His alternative is an agreement among the United Nations to prohibit the production and use of atomic weapons. When asked at a subsequent meeting how a nation could be assured it would not be destroyed by a surprise attack unless inspection guaranteed against manufacture, he said: "No inspection as such can guarantee peace and security. This idea of inspection is greatly exaggerated in importance. It is a too-superficial understanding of the problem of control. The only real underlying method of control is by the unanimous cooperation of the United Nations."

In an address given by former President DE GAULLE of France on July 28 he said:

"The time is short to build the peace and to create the organization that should make it strong.

"Everyone is gaging the hidden threat that, because of this, weighs on civilization. Everyone understands that nothing is more imperatively necessary for all peoples than to organize in common the research, production and control of atomic energy in such ways that it will serve for economic and social development and that it can never be employed for war.

"We must say on this subject that the proposals made by the United States to monopolize everything concerning the matter in an international compulsory organization seems right and good to us. At any rate, it must be added that there is open a duty toward humanity that infinitely surpasses the interests and claims of all regimes and all nations. If the task is not fulfilled, a cloud of danger will weigh on all who live, but if it is we shall doubtless finally see born the international cooperation that is the only conceivable road to peace and safety for humanity."

experience, to responsible executive positions, that the full benefit of science can be derived by industry.

The Mond Nickel Co. has invited the cooperation of the leading British metallurgical institutes and has proposed that the detailed implementation of their proposal should be worked out by joint action. The fundamental problem of the shortage of metallurgists is one that urgently requires the most rapid solution possible, and the company has therefore proposed that the whole of the $250,000, and accrued interest, should be expended during the next 10 to 15 years. On this basis it is estimated that at least five fellowships of substantial value would be available each year.

WILLIAM GRIFFITHS
Managing Director
Mond Nickel Co., Ltd.

Platinum Refining and Melting

GLASGOW, SCOTLAND

To the Readers of METAL PROGRESS:

Handling of platinum scrap shows little progress with time. The volume of the material is so small and its intrinsic value is so high that there is little opportunity or urge to conduct independent investigations. Likewise a major trouble is the extreme secrecy maintained by most of the platinum refiners themselves — they cannot make good contact with those engaged in refining the other rare metals.

A case in point is the failure to adapt the induction furnace to the melting of unalloyed scrap platinum. The method consisted of placing a very small piece of platinum scrap in the bottom of the crucible, and once the current had been sufficient to melt this, to make further additions. With the conventional blowpipe arrangement, on the other hand, a much larger amount of platinum could be melted at a time without difficulty, once the conditions had been properly standardized. The need for accurately maintained conditions will be appreciated when it is mentioned that one firm paid $2500 to a so-called expert for details of how to operate such a furnace consuming coal gas, whereas the complete outfit of blowpipe or "torch", a carved piece of lime and the molds only cost $10 to $15. A fresh lime block has usually to be carved out for each succeeding operation, but the wide difference from induction furnaces in total outlay will be apparent. The procedure, however, requires skilled attendance; for various reasons the metal may "spit" seriously on cooling, a phenomenon similar to the sprouting of silver by entrapped gases.

*Outlined in *Metal Progress* for May, page 992, and for July, page 83.

Much of the scrap platinum is alloyed jewelry, dental alloys or electrical contacts. This is usually melted with silver and arsenical lead, some poor copper-lead matte and a covering slag. The silver, gold, platinum and palladium go into the lead button, the intermediate speiss-matte contains the iridium, rhodium, ruthenium and osmium. The lead is oxidized by cupellation and the silver (containing about 1% Pt) is cast into plates and electrolyzed. The slimes contain the platinum, but even so they may analyze no more than 4% platinum, most of the rest being gold. Gold and platinum are put into solution by hot aqua regia plus hydrochloric acid and the gold then precipitated by $FeCl_2$ and the platinum last by NH_4Cl. The platinum precipitate is converted to a sponge (about 990 fine) by gentle heating in a closed crucible. All residues are recirculated for retreatment. This sponge platinum is broken up by rubbing, sifted, dampened with water, and strongly compressed into small cakes, before placing it in the lime block of the gas-burner furnace. In the electric furnace there is some danger of a minute amount of calcium entering the platinum; magnesia refractories are more guilty of contamination, and have been discontinued for this reason.

The blowpipe does not differ from many familiar in other industrial pursuits; it has a double metal tube, one of which conveys gas, the other oxygen. Should the gas mixture be improper, the molten platinum is liable to absorb gases; if this defect is apparent the product has to be remelted. A water-jacketed blowpipe is usually preferred, to prevent exuded particles from the tip entering the platinum. The lime blocks take the form of an upper and a lower carved section which are bracketed together to form a crude furnace, with a space for the products of combustion to escape.

A certain unwillingness to use the arc electric furnace was from the fear that some of the platinum might be volatilized and because of the supposed possibility of contamination with carbon. In the attempts that were made the conditions of the arc were not properly understood.

Methods recently used widely for the casting of high temperature alloys (gas turbine blades and diaphragms) are also available for casting platinum. In this an electrically heated crucible of lime and mold are constructed in one unit and, when the metal is molten, the unit is spun in a horizontal plane so the mold is filled and solidifies under centrifugal pressure. In this way there is no influence which can interfere with the formation of a solid block of metal. The total time is only a matter of minutes when dealing with charges of one or two ounces.

C. C. Downie

Russian Metallurgical Literature

New York City

To the Readers of Metal Progress:

Receipt of the latest book by George Akimow, an occasional contributor to these columns from the U.S.S.R., warrants one or two observations. The book is on the study of metallic corrosion, and is such an excellent supplement to the older English book by Ulick Evans that it is to be hoped Akimow's book will be translated. It suffers from showing few influences of non-Russian work since 1938 or 1940, but this is probably due to wartime postal troubles rather than to design. Particularly interesting are the transliteration of some English words like "pitting" and "intercrystalline" into the Russian language. This circumstance should perhaps give us a ray of hope that sometime the scientists of the world at least will speak the same language.

V. N. Krivobok
Chief Metallurgist
Development & Research Division
International Nickel Co.

A Diagnosis

Pittsburgh

To the Readers of Metal Progress:

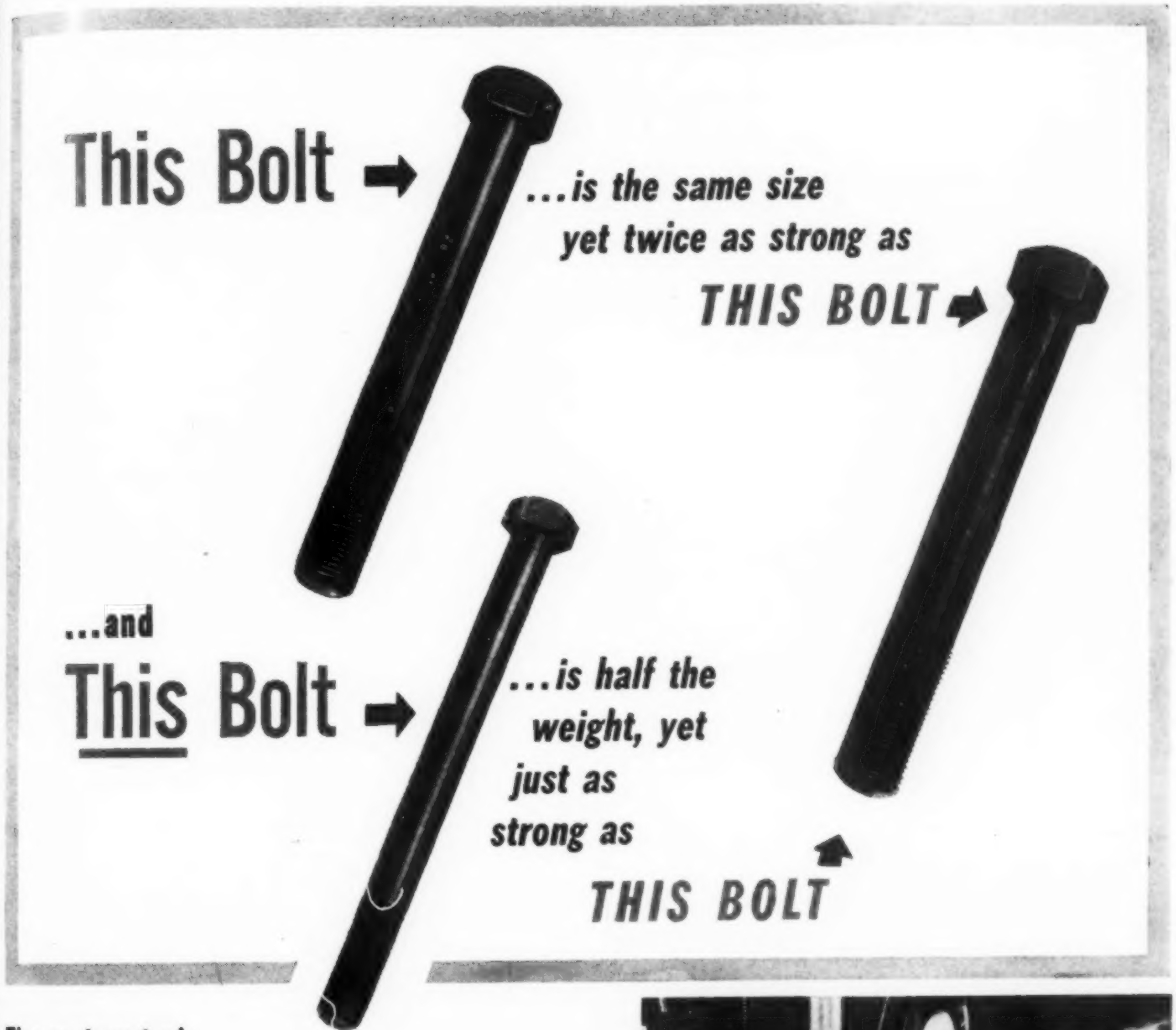
For some time I have believed that many of our current troubles stem from unbalanced labor legislation, fantastic recipes for an economic Utopia, and vicious politics. I now find that I might be wrong, for I have just received the following communication from an exceptionally able engineer whom I regard most highly. In the course of a witty letter he says:

"What with time lost in commuting and the attention required by the multitude of new engineering problems I have been plunged into, I hardly find enough time to go through the accumulation of things thought up for me around the house and car by my wife and family each week end. The kind of logic that leads a woman to conclude that putting up a fence around a flower pot is more important than the development of a new type of reduction gear is the kind of thinking that is leading this country to pot."*

It is possible that you too would like to be corrected as to what is wrong with the country.

William B. Brooks
Metallurgist and Welding Engineer
Alloys Development Co.

*Or read: "The kind of logic that leads a man to conclude that the development of a new type of reduction gear is more important than putting up a fence around a flower pot is the kind of thinking that is leading this country to pot."

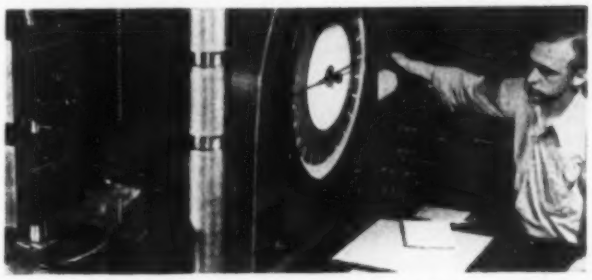


These treated NICKEL ALLOY STEEL BOLTS will develop 100% greater unit tensile strength than untreated carbon steel bolts

Whether you aim to gain greater holding power, or save weight and gain space, these Nickel alloy steel bolts will help you.

If bolt holes are already in the part, ¾" heat-treated 3135 or 8635 Nickel alloy steel bolt gives twice the holding power of a ¾" untreated 1020 carbon steel bolt.

On the other hand, if bolt holes are not in, and design does not permit a ¾" bolt, remember a ½" bolt of the same Nickel alloy steels, heat treated, gives almost as much holding power as a ¾" untreated 1020 carbon steel bolt, *and weighs less than half as much.*



Tensile testing Nickel alloy steel bolts at the plant of Lamson & Sessions Company, Cleveland, Ohio.

EMBLEM OF SERVICE INCO Nickel

TRADE MARK

Over the years, International Nickel has accumulated a fund of useful information on the selection, fabrication, treatment and application of alloys containing Nickel. This information and data are yours for the asking. Write for "List A" of available publications.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

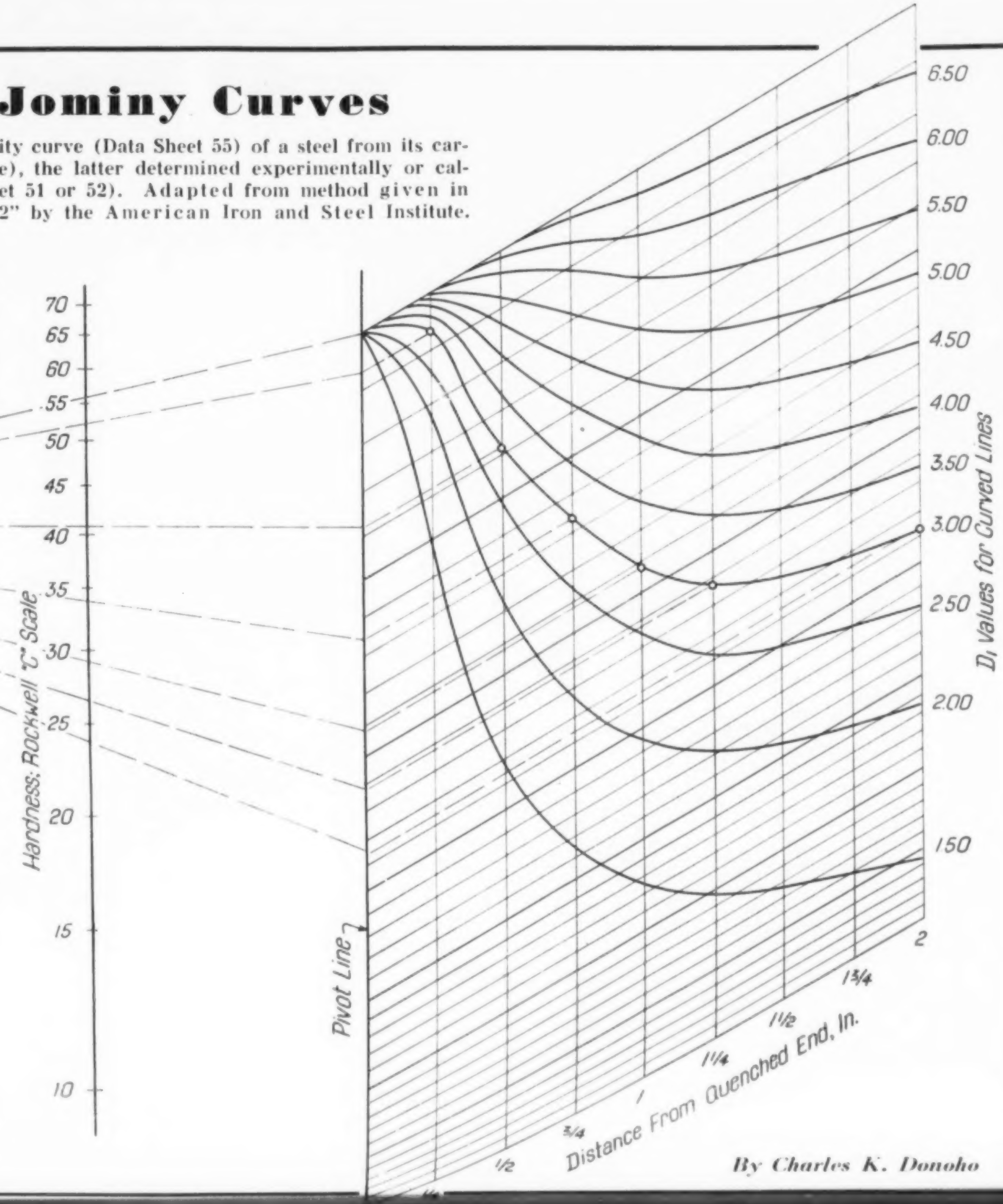
Calculation of Jominy Curves

Nomogram for estimating end-quench hardenability curve (Data Sheet 55) of a steel from its carbon content and its ideal hardenability (D_1 value), the latter determined experimentally or calculated from its chemical composition (Data Sheet 51 or 52). Adapted from method given in "Contributions to the Metallurgy of Steel, No. 12" by the American Iron and Steel Institute.

Example is worked out for a 0.40% carbon steel with D_1 of 3.00. First ray to give initial or $\frac{1}{16}$-in. hardness is drawn from 0.40% carbon on the left-hand scale to the pivot line at the common origin of all the D_1 curves. (The initial hardness depends only on the steel's carbon content.) Subsequent rays are drawn to points *on the pivot line* determined by following the slanted scale downward and to the left to the pivot line from the required Jominy distance and D_1 value (in this example, the $D_1 = 3.00$ curve). Scale hardness from the center scale:

Distance on Jominy Bar	Rockwell Hardness
Initial, or $\frac{1}{16}$ in.	C-56
¼ in.	C-52
½ in.	C-41
¾ in.	C-34
1 in.	C-29
1¼ in.	C-27
2 in.	C-24

Obviously the operation can be done backward, and thus estimate the ideal hardenability D_1 if the Jominy hardness curve is known.



By Charles K. Donoho

Substitute Metallurgical Products

By Albert M. Portevin
Bessemer Medalist
Consulting Engineer

Translated From the French
By William M. Baldwin, Jr.
Metallurgical Engineer
Chase Brass & Copper Co.

WARTIME INTEREST in substitute products will be carried over into peacetime as an interest in material economy, because shortages and high prices will continue until such time as a new commercial equilibrium is established. Substitute products and material economy are thus related subjects. A brief description of the wartime shortages of metals in France has, therefore, more than mere historical interest. Many of the substitutions that were forced upon us were endured only because of extreme necessity and were abandoned with eagerness; some were of sufficient advantage to warrant continuance even in times of abundance. At any rate, it has enabled my professional brethren to make a clearer appraisal of the real requirements of many metallurgical usages, and it will therefore be my aim to set forth first the substitutes used for conventional steels, and next the wartime changes in applications of the common nonferrous alloys. Lastly, a presentation of some general considerations that will apply to any appraisal in a more normal free economy will be reserved for a later communication. Even if the problem of substitute materials is no longer a pressing one, it has not been completely eliminated, and it would be well to consider the whole problem so as to draw whatever general conclusions that can be of use.

There are not, strictly speaking, two equivalent materials capable of mutual substitution by virtue of identical properties; they must differ at least in some respects, otherwise they would be the same substance, since properties are only the expression of the material and its structure seen from all aspects. Consequently, we will call a substitute any other metal which can, *under certain conditions,* be used in place of a given metal or alloy *for a specific application.* Substitution will be possible, one material for another, if there is a certain equivalence or similarity from the standpoint of use, and only then.

Use will require certain properties which the metal must have in sufficient quantity for the piece to give satisfactory service. The properties will depend on the part and the use to which it is put. Thus, we can speak of substitutes for certain applications, but this does not permit any generalization to be made to the effect that one alloy can be substituted for another (without specifying both the parts *and* their use).

For example, a particular zinc alloy may be substituted for a particular brass for a particular part, but we cannot say in general that zinc alloys are substitutes for brasses.

With these brief introductory remarks, let us proceed to specific examples, first of steels, then of nonferrous alloys.

Substitution Steels

Substitution alloy steels have received much study and work — before the war in Germany, in preparation for the conflict, and during the war in France, as a result of dictates to which we were subjected. Much successful work has also been done in America. To review the French situation, we can do no better than to summarize the conference held on May 13, 1945, at our request, by André Sourdillon and under the auspices of *Rayonnement Français* with the representatives of the Allied Expeditionary Force.

Steels Used at the Beginning of the War — To start with, the adjoining tables list the essential

special or alloy steels used in 1940, separating them into three classes: A. Structural steels used at ordinary temperatures; B. Structural steels used at elevated temperatures; C. Toolsteels. Inspection of the tables shows that Class A contained considerable nickel or chromium or both; Class B contained relatively large amounts of both nickel and chromium; and Class C depended on an ample quantity of tungsten or molybdenum. The greatest tonnage went into the structural steels of Class A, and in particular into chromium-nickel-molybdenum steels. These made the essential parts of automobiles or heavily armored vehicles as well as protective parts and armor for tanks and artillery, and they were considered to be of very high quality.

Class A: Structural Steels Used in 1940

Type	Addition Elements					Treatment
	Ni	Cr	Mo	Al	C	
Nickel steels	2 to 5	—	—	—	0.10 0.30	Casehardening Quenching & tempering
Cr-Ni-Mo steels	2.5	1	0.4	—	0.10 0.30	Casehardening Quenching & tempering
	3.5	1.5	0.4	—	0.30	Air hardening
Cr-Mo steels	—	1.5	0.2	—	0.10 0.30	Casehardening Quenching & tempering
Cr-Mo-Al steels	—	1.5	0.2	1.0	0.3	Nitriding

The Effect of Occupation on Supplies — The occupation and consequent German control brought about the progressive reduction and ultimately the disappearance of these addition elements. In 1943, O. d'Heil, director of the *Reichstelle* in Berlin, appraised the supply question in the following manner:

"Nickel does not even enter commerce at this time. It is too precious for any except most essential work.

"Molybdenum likewise is on the point of disappearing and it can only be tolerated for exceptional uses outside of toolsteels. Supplies are cut off from Morocco by the blockade.

"Chromium, on the other hand, is being produced in the Balkans in important quantities and supplies are augmented by certain reserves from Turkey. [This element could be used abundantly enough until 1943, but thereafter in progressively reduced quantities.]

"Almost all sedimentary ores contain some vanadium. The German process of recovering this metal from Thomas slags by forming vanadic acid, yields relatively important quantities of ferrovanadium.* Supplies in this metal are adequate."

Class C: High Speed Toolsteels Used in 1940

Analysis				
W	Cr	Mo	V	Co
14	4		0.5	
18	4	1	1	
21	5	1.5	1	5 to 10
2	4	10	1	

Finally, manganese rapidly came to be the basic addition element in the steel industry. But if "European" production could amply cover consumption requirements in 1942, it was necessary, according to German authors, to use the entire production of the Russian Donetz mines, whose high manganese content permitted only the production of the newer (substitute) steels. However, the Russian army retook Nikopol in 1943.

To sum up, the various additions could be listed in the order in which they were increasingly more available: Nickel, molybdenum, tungsten, chromium, vanadium, manganese. They successively replaced each other in special steels, which thus tended toward becoming simple carbon steels.

Equivalence of Addition Elements — Addition elements are put in steels to effect certain favorable physical properties such as:

1. To decrease the critical quenching rate or (what is directly related) to increase the depth of hardening, or what has become known as the "hardenability" of steel.

2. To decrease the hardening temperature, and thus reduce distortion during quenching.

3. To decrease the tendency to overheat, or cause austenitic grain growth at elevated temperatures, which leads to structural weakness, or which requires precautions to avoid it, or supplementary treatment to remove it.

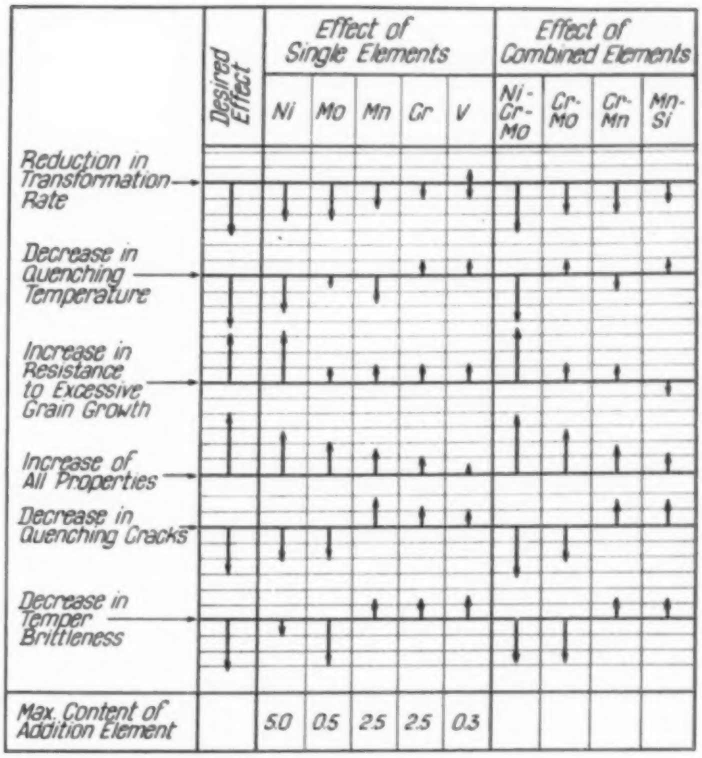
4. To increase the group of mechanical charac-

Class B: Steels for Special Use (1940)

Analysis				Uses
Ni	Cr	W	Si	
—	10	—	3	Exhaust valves
10	20	2.5	1	Exhaust valves
35	10	—	—	Exhaust valves
15	22	6	—	Heat resistance
60	12	2	—	High temperature corrosion resistance
8	18	4	—	High temperature corrosion resistance

*See "General Review of German Metallurgical Practices", by John H. Frye, *Metal Progress*, January 1946, page 81.

Fig. 1 — Effect of Alloying (Addition) Elements on Structural and Engineering Steels (After Sourdillon)



teristics obtained after thermal treatment — in particular, for a given value of the ultimate strength — such as the value of the yield point, the endurance limit and, most of all, the elongation and impact strength. For carburized steels, especially when used full hard, the last two characteristics should exceed a minimum value.

5. To diminish quench cracks.

6. To diminish temper brittleness.

The effect of these addition elements, in obtaining the above objects, is different in intensity and sometimes in direction, as may be seen in Fig. 1, where an attempt has been made to summarize these tendencies in a simple qualitative manner; the arrows indicate, by their length and direction, the amount and direction of the modification that can be obtained in steel with the usual alloy additions.

The diagram shows a similarity in the effect of the first three elements (nickel, molybdenum, and manganese) as far as the hardening rate and transformation temperature are concerned, but a marked divergence in other properties. Thus, prevention of large grain growth is actually attained with nickel only; steels lacking this element are susceptible to overheating. Furthermore, temper brittleness, avoided by the specific use of molybdenum, is not eliminated by other elements in steels free of molybdenum, especially those high in carbon. Lastly, quench cracks would be frequently encountered in high manganese steels. It will also be noted that chromium and vanadium operate in the same direction, with some variation in intensity depending on the conditions of use.

In general, elements with similar effects reinforce each other, and in particular, chromium may be used to advantage with other elements to form favorable complexes. Among those combinations of alloys listed, Ni-Cr-Mo is the one which meets the most requirements of industry.

The bottom line of Fig. 1 sets the maximum alloy content, all things being taken into consideration. Two of them, molybdenum and vanadium, which are effective in extremely small amounts, are particularly interesting in these times of shortages.

Properties and Service Performance — In general, the evolution of the addition elements in the substitution steels was effected thus:

1. Down-grading of prewar steels containing nickel, to lower its con-

Compositions of Principal Types of Substitute Steels Used in France

Type and Date	Ni	Cr	Mn	Mo	V	C	Treatment
Nickel-chromium (1940 to 1941)	1.3	1.5	·0.8	0.2	0.05	0.10 0.30	Casehardened Quenched & tempered
	1.1	2.0	i	0.2	—	0.15	Casehardened
Chromium-molybdenum (1940 to 1941)	—	1.2	0.9	0.10	—	0.10 0.30	Casehardened Quenched & tempered
Chromium-manganese-vanadium (1942 to 1943)	—	1	0.9	—	0.2	0.15	Casehardened
Chromium-manganese (1942 to 1944)	—	1	1.2	—	—	0.15	Casehardened
	—	1.3	1.3	—	—	0.22 0.35	Casehardened Quenched & tempered
Manganese-silicon (1944 to 1945)	—	—	1.3	1.2 Si		0.35	Quenched & tempered

*i represents incidental amounts residual or necessary in the steelmaking process; silicon is incidental except in the Mn-Si steel last listed.

— means none, or a low fraction of one per cent residual from scrap or recovered from other raw materials.

tent to the vanishing point, by substituting chromium or chromium and manganese.

2. Modifying the chromium-molybdenum and chromium-vanadium steels.

3. Creating a chromium-manganese-molybdenum steel; then one without molybdenum.

4. Reintroduction of a manganese-silicon steel when all other addition elements were prohibited.

The analyses of the more typical of these steels are indicated in the adjoining table. It can be seen how the addition of the more precious elements decreased gradually until only the last two with chromium, manganese and silicon were authorized — and then with heavy restrictions — early in 1944.

If this measure produced an important saving in special elements, it led us slowly to the conclusion that any of the elements but carbon itself would soon be a rare and perhaps superfluous addition!

These steels can be compared with steels used previously according to the properties obtained or according to results in service.

Properties — These steels were used in the heat treated condition, either carburized, or quenched and tempered, the properties depending on the mass of the piece and the depth of hardness — the latter determined by the analysis and the heat treating conditions. For the purpose of simplification, the depth of hardness could be described by the hardness curve across the diameter of a hardened (but not tempered) cylinder of proper diameter, and the mechanical properties could be evaluated as a function of the drawing temperature after quenching. Usual properties determined were ultimate strength, elastic limit, elongation and notch impact strength. These are shown for some steels of special interest in the adjoining diagrams.

In the left portion, a comparison is made between the three substitution high strength steels designed for casehardening. The first steel, containing only 1% nickel but with considerable chromium, gave properties almost identical with those of the best prewar varieties as far as high impact strength in the hardened condition is concerned, as well as for high hardness penetration.

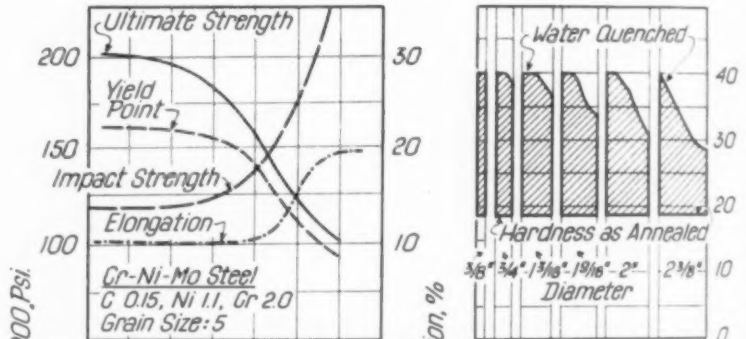
The second steel, a mild chromium-manganese steel, of the same strength as the preceding one, had impact strength and hardness penetration sensibly less, so that it would possess only the properties of the core in parts with large cross section. The lower left is a steel of the same type as the second with a little higher carbon content; it has still lower impact strength, but generally better hardenability.

These curves show how a slight variation in the essential elements, carbon, chromium and manganese, radically affect the properties of the steels, and how sensitive their bulk hardness is to the section size of the hardened piece.

The diagrams at the right of the group represent three half-hard steels used only as quenched and tempered. The first, of a prewar type, is characterized by its good impact strength in the quenched condition and its good hardenability — being completely hardened in $1\frac{1}{4}$-in. rounds.

The other two, both chromium-manganese

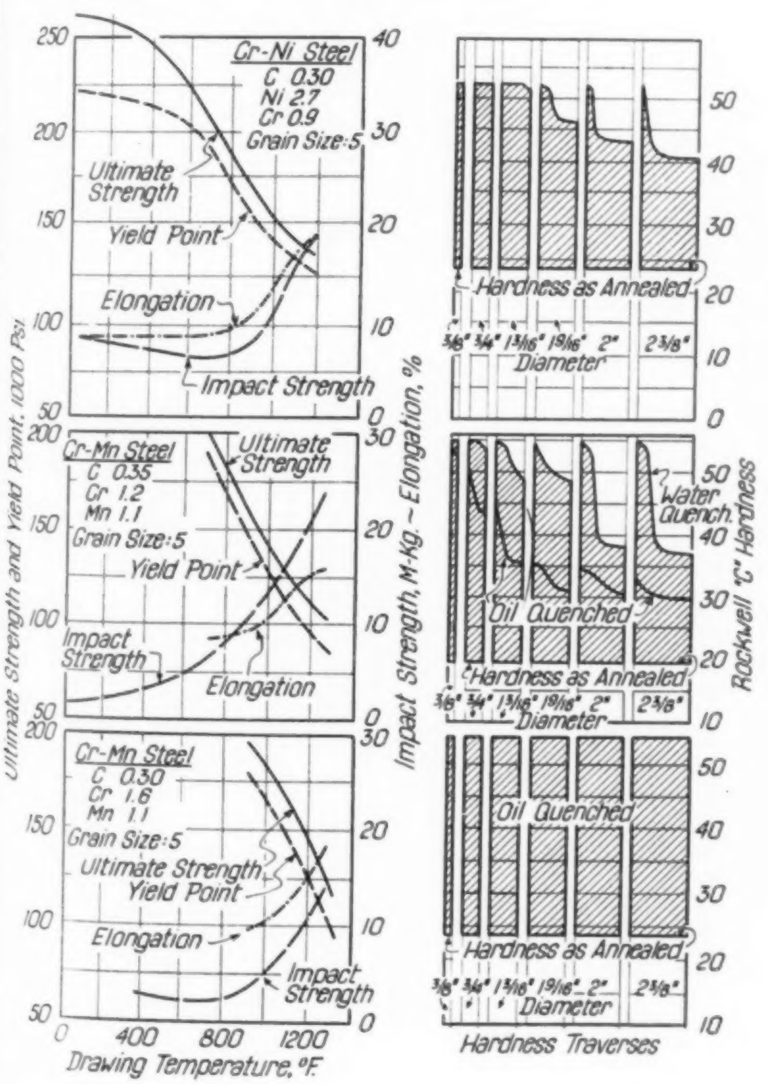
Fig. 2 — Comparison of Mechanical Properties and Hardenability of Substitute Steels Used in France. Below are diagrams for three carburizing steels; on page 489 the diagram shows three steels for general use in highly stressed parts



steels, have the same disadvantages as the carburizing steels of the same type: Their elongation and impact strength in the hardened state is such that they are useless unless drawn to 1000° F. or higher.

Here again, slight variations in composition radically affect the mechanical properties — in particular, the steep portion of the curves for elongation and impact strength versus tempering temperature. This requires close control of steel composition, grain size and heat treatment. It also prevents their use at elevated temperatures.

Furthermore, if impact strengths at equal strengths are compared, either after a low draw (approximately 500° F.) or after a considerably higher one (approximately 1200° F.), the substitution steels appear definitely inferior. On the other hand, systematic tests conducted by the Air Ministry have shown that the endurance limit either at a given strength level or at equivalent impact strengths were higher for the substitution steels than for the older steels — results which a number of German investigations have confirmed for gear teeth. From the latter point of view the chromium-manganese steels, in particular, have some advantages. There are some applications in which the parts are subjected either to high fatigue or to triaxial loading without shock for which the new steels appear to be superior to the old. Furthermore, a slight improvement in hardness and wear resistance appears to be obtainable.



Practical Results — Results of service performance can be summarized as follows:

1. The substitution of steels low in nickel for the older steels richer in nickel was effected with no trouble. If they sometimes presented difficulties in annealing before fabricating or in casehardening, they had very good properties. It would appear that they will be developed and used, in the future, at the expense of the older alloys.

2. The most distinctive behavior of the replacement steels was that they had only a slight hardenability. This requires the metallurgist to increase the carbon content, which in turn leads to brittleness. The uniform penetration of hardness was not as good in parts with variable cross section as in the older steels. In casehardening, for example, the ultimate strength occasionally attained very high values in thin sections, whereas massive sections hardened insufficiently.

These characteristics, despite the higher endurance limits, make it necessary to discriminate in using these materials, when the service, shape and dimensions of the piece are taken into account. Thus, gears — not heavily loaded but subjected to an underestimated shock or impact — have failed; whereas the new steels have performed well for heavily loaded gears not subjected to impact, because of the higher endurance limit. In such uses high quality steels considerably harder than those chosen heretofore may be employed in the future — the impact strength being of less importance than previously thought.

This discrimination was rigorously applied at the beginning of 1944 to limit the use of the new steels, taking into account both the properties and the principal dimensions of the piece, simple carbon steels being used for all parts with thin sections, especially when subjected to high stresses. Some of the important precautions involved the welding of such substitute steels at definite temperatures, the carburizing at a lower temperature and in less active cement (to avoid carbide precipitation

in a brittle network), a rapid quench following tempering, to avoid temper brittleness or the visible reprecipitation of carbides.

Since these steels distort more on quenching, and are more susceptible to cracking, they require a high precision in the control of factors governing these operations. In this respect, time quenching, austempering, and superficial heat treatment (either by flame or by high frequency induction devices) appear to be efficacious in reducing these defects.

Generally speaking, it was thus possible to economize in the use of the important addition elements in structural and engineering steels, and get along with the resources at our disposal. The same methods for economizing were applied to the other classes of steels that represent a much smaller tonnage — toolsteels, in particular.

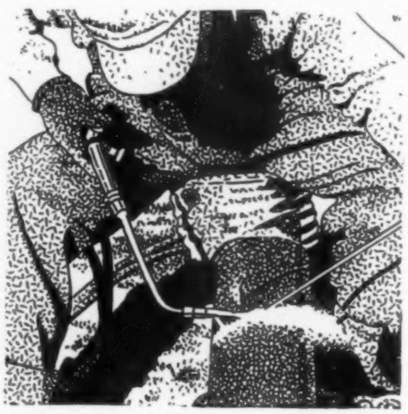
Substitution Toolsteels — The predominant element in these alloys was tungsten, whose rapid disappearance forced us to replace it with vanadium and chromium. Among the numerous compositions tried, the following were retained:

W	Mo	V	Cr
10	1	3	4
6	5	2	4
3	3	3	4

Opinions regarding the cutting ability of these steels were very divergent. The richest grade listed above seemed to be equivalent to the old 18-4-1, the leanest to the old 14-4-1.

Everyone, however, was in agreement that the heat treatment of these steels — which were much more sensitive to overheating and to decarburization than the old — should be carried out with much greater care than formerly. Some new methods were useful in improving properties; here, as in the case of structural steels, future development will tend toward the 10% tungsten steel which saves nearly one-half of this rare element.

General Conclusions — With continued improvement of these substitute steels, of their heat treatment (especially their surface heat treatment), and with a better knowledge of the distribution and value of internal stresses in mechanical parts, it may be possible in the future to manufacture much equipment with the newer steels that is comparable to the older. In the future, too, it may be possible to obtain either a reduction of the rarer addition elements, or a reduction in the amount of special high property steels used by machinery makers.



Welding and Resurfacing

Worthwhile economy was achieved in the field of welding and resurfacing either with the oxy-acetylene flame, atomic hydrogen process, or the gas-air torch. We will cite a few examples:

Rails — Railroad rails wear principally at their ends. This constitutes a considerable expense that can be alleviated best by welding them end to end, increasing the solid length from 60 ft. to 180 or 300 ft., thus reducing maintenance costs due to wear of the butt ends by 60 to 80%. The inevitable wear at the ends of these longer units can be repaired by building up the surface and grinding the deposit smooth.

This scheme is also used to repair worn or cracked austenitic manganese steel frogs and crossings. In this operation it is necessary to use a micrographically identical metal — that is, austenitic on air cooling (or on quenching if necessary); therefore, 18-8 electrodes are used for filling cracks, and 13% Mn, 5% Ni electrodes for resurfacing. Care must be taken, when using the latter, to cool the web of the rail with water, by means of wet cloth or otherwise, while the successive beads are cooling on the rolling surface.

It is worth mentioning at this point that one mile of main-line railroad track, the rail weighing about 180 tons, can be repaired in a few days by two workers with the use of oxy-acetylene equipment, and 225 to 325 lb. of metal! The over-all economy of this operation can be realized.

It should be mentioned, too, that the quality of the metallic deposits can be improved by introducing elements such as manganese and chromium in quantities up to 1%.

Propellers — Cavitation produces erosion on the leading edge and face of ship propellers. When the Normandie was first put into service, such erosion required a change of screws (20 ft. diameter, 27½ tons weight) every two months. Later they were rebuilt by atomic hydrogen welding; resurfacing required a deposit of 675 lb. of metal, laid down in 410 hr., for two screws.

Rebuilding Tools — In tools, only the cutting edge itself requires the cutting properties due to the presence of alloying elements. Their consumption can thus be limited to the working part of tool only, which can be repaired by resurfacing by torch or arc fusion.

For example, tractor tread links were repaired with cast iron containing nickel and chro-

mium added to give the necessary wear resistance. Plowshares which had to be reforged had their cutting edge protected with a chromium steel that could be forged. Tools were resurfaced with a high speed steel or a Stellite type of alloy (high in cobalt, tungsten and chromium). Similar means were used to repair seats or valve heads for exhaust valves.

By virtue of the high carbon in high speed steels, a hardness of Rockwell C-62 to 64 exists in the weld deposit without further heat treatment if the weld is rapidly cooled. This is sufficient for cutting the emergency steels. With heat treatment, Rockwell values of C-68 to 69 are possible.

Resurfacing of machine parts with steels and alloy irons is becoming known as *crinitage,* and effects a considerable economy in the use of special addition elements that would be required if an entire new part were to be fabricated.

Nonferrous Metals and Alloys

Developments in the situation with regard to nonferrous metal resources during the war can be described by mentioning the scarcity of copper and tin (to say nothing of nickel, already discussed above), then the steadily increased use of aluminum in aviation and — later — the scarcity of zinc.

Since the use of tin-base alloys, such as bearing metals and solders, was distinct from that of copper alloys, it will be discussed separately.

Copper and Copper Alloys — Copper is primarily used because of its high electrical and thermal conductivity, its excellent ductility (which allows production of fine wires and sheets), and its corrosion resistance.

For those electrical applications where copper wire is used for conductivity and its availability in fine sizes, pure aluminum wire can be substituted down to 30 gage (0.012 in. diameter), or aluminum alloyed with small amounts of magnesium in sizes down to half as large. Substitution of aluminum for copper cannot be made if certain corrosion conditions such as marine exposures are present.

Aluminum can likewise be substituted for copper where the latter is used because of its thermal conductivity and its formability, such as fittings for the chemical industry, distilleries, food processing. As before, certain corrosive conditions, such as saline solutions or various mineral or organic products, limit its use. Some applications of copper where its *thermal* properties are of paramount importance, cannot be replaced, such as tuyeres in blast furnaces and blowtorch nozzles.

Lastly, the plasticity of copper is used to advantage in certain applications such as in rotating bands for artillery projectiles. For this, pure iron, electrolytically deposited, was substituted in the 1914-1918 war, iron powder compacts in the last war, and, as has been pointed out by the present author, black heart malleable iron.

Brass — Brasses are used because of the ease by which they may be formed either by rolling, drawing or stamping, or by machining. At the same time, they have greater tensile strength than copper.

1. Brasses for rolling, drawing, or stamping are the alpha brasses rich in copper. Aluminum, either pure or slightly alloyed, was used for deep drawn parts such as cartridge cases. Even extra mild steel was used in some substitutions like bullet jackets. Cartridge cases of all calibers were formed of plain carbon steel containing 0.15 to 0.20% carbon.* Radiator tubes, coils, or condenser tubes — where corrosion, and especially marine corrosion, is a factor — 70-30 cupro-nickel, or 8% aluminum bronze, or brass with 1% tin or 2% aluminum were used, and these could not be replaced.

2. Brasses for machining are the free-cutting brasses (alpha plus beta) with 1.5 to 2.0% lead. These alloys were replaced by high sulphur steels, and sometimes by light alloys. Zinc alloys with bismuth or thallium additions, which will be described later in the report, were also used in certain substitutions.

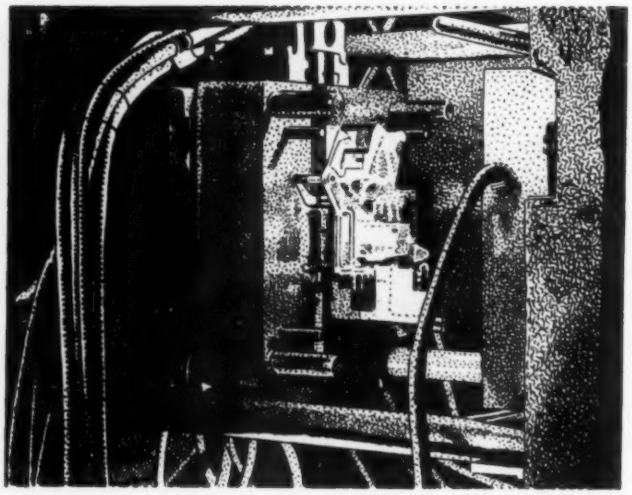
Copper Foundry Alloys — Attempts to substitute aluminum for brass and bronze castings — for example, fittings — were started but were not carried through, since it was necessary to abandon aluminum for zinc. In certain common applications, corrosion resistance is essential; aluminum in such parts requires anodic protection.

Aluminum and Aluminum Alloys — Aluminum alloys are used because of their low density — a property that cannot be obtained otherwise except in magnesium alloys. The latter are more costly to produce, more readily oxidized, and less stable, especially where saline corrosion is concerned. Moreover, the available protective methods for magnesium alloys were less efficacious than, for example, the anodic oxidation of aluminum.

In view of the small amount of virgin aluminum allocated for French use, the recovery of scrap (always plentiful in wartime) became an important factor. The scrap was segregated according to alloy group, since certain cross-mixtures must be avoided. For accurate segregation, chemical analysis is frequently necessary; when faster work is required, certain spot tests can be used, such as color tests requiring reagents (like caustic soda, hydrochloric acid, nitric acid, cadmium sulphate). Scratch hardness tests are also of value.

Once the scrap is segregated it is melted under

*See a rather complete account of German practice in *Metal Progress* for March 1945, page 491.



flux, which effects some purification. These fluxes are based on alkaline fluoride salts to which chlorides are added to lower the melting point; their principal action is to dissolve the aluminum oxide on the scrap and cause the droplets of molten metal to run together. Despite the best we could do, we found that high quality alloys still required virgin metal; recovered alloys should be reserved for second-grade parts.

Tin Alloys — Tin is the base for two principal alloys in which its low melting point, antifrictional properties, relative resistance to oxidation, and its miscibility with other metals, are put to play. These are *(a)* antifriction alloys intended for coating bearing surfaces in varying thicknesses, an operation known as lining or babbitting, and *(b)* solders with low melting points used in joining parts without fusion of the basis metals.

The scarcity of tin was felt likewise in the United States, and as there, we in France had to adopt the following measures:

1. Reduce the lining thicknesses in bearings.
2. Use alloys without tin or with a minimum.
3. Recovery of as much as possible of white metal scrap or fusible alloys containing tin in combination with lead, antimony and copper.

Modification of the conventional antifriction alloys was along the following lines: For centrifugal castings, lead-base bearings were adopted with a maximum of 12% tin with at least 16% antimony to avoid brittleness and a small amount of copper (0.8 to 1.5%) to prevent segregation due to density differences. An alloy with 12% tin, 14% antimony, 0.8% copper — or 1.5% copper with 2% cadmium — to reduce deformation under load — was typical.

For gravity castings, a lead-base alloy with 10% tin and 10% antimony was adopted for better castability. As will be discussed later, zinc-base alloys were even substituted in some instances as a tin-free antifriction alloy.

However, it is important to note that the various antifriction alloys should be compared on the basis of the properties required by service, as was brought out in "Choice of Acceptance Tests as Exemplified by Antifriction Alloys" appearing in the correspondence pages in the November 1945 issue of *Metal Progress*. In particular, the alloy should possess sufficient plasticity under constant load; this is determined by creep tests in compression at definite temperatures. Deformation is found to be a function of time, t, as follows:

$$D = \mathrm{k}t^{\mathrm{m}}$$

It is important that the exponent m be as large as possible. For loads giving a 1% compression in 200 hr. at 40° C., for example, it was found that the order of magnitude of the exponent, m, was:

m = 1.0 for tin-base antifriction alloys
m = 0.6 for lead-base antifriction alloys
m = 0.4 for zinc-base antifriction alloys

Solders — The standard solders in France as in the United States were tin-lead alloys whose tin content varied from 40 to 60%. These alloys grew up in the trade without any systematic study. To lower the tin content, an analysis was made of the properties desired, correlated with the constitution diagrams and the cast structure. It was immediately apparent that poor castability and the presence of dross in solder having a low tin content (10 to 20%) was due to the presence of traces of impurities (copper less than 0.1%, iron less than 0.05%) which it was necessary to avoid.

In studying the mechanism of melting during soldering, it was determined that when soldering with a soldering torch the alloy is brought to a pasty state and the solidification range must be sufficiently broad. The better solders among the lead-rich alloys are those in the vicinity of 20% tin — even a 15% tin alloy has a solidification range that is broad compared to a 33% tin solder.

On the other hand, when soldering with a soldering iron the alloy is completely molten. Therefore, it is only necessary to consider the fusibility and adhesion of the solder. For the soldering of zinc, iron or copper a low tin content is theoretically sufficient to obtain adhesion since these metals are readily soluble in liquid tin. Consequently, solders with 12 to 20% tin can be used. It is only when it is desired to limit the temperatures involved — as when soldering tin plate so as not to exceed the melting point of tin — that it is necessary to use the eutectic alloy (with 40% Sn). For aluminum, solders must contain zinc (in which aluminum is soluble) to obtain bonding. Hence the standard solders for aluminum are either zinc-tin or zinc-cadmium base alloys.

On the basis of systematic studies on the melting points of zinc, aluminum, copper, magnesium and antimony alloys, M. Dannemuller chose a eutectic zinc alloy with 3.2% magnesium, 2.8% aluminum with a melting point of 660° F. This is a little too high for soldering very fine pieces; for the latter, he selected a ternary eutectic of lead-cadmium-tin with an addition of 30% zinc. On the other hand, soldering aluminum with metal-flux powders requires a very dense alloy; a typical example is a lead-base alloy with 3 to 4% zinc for adhesion and 3% tin or 8% cadmium for miscibility.

Recovery of White Alloy Scrap — White metal scrap (after the iron is separated magnetically) furnishes a complex alloy of Pb-Sn-Sb-Cu that is usually treated by liquation, either natural or induced by adding other metals that produce a crystalline compound with certain undesirable constituents of the bath. This treatment has been improved considerably by scientific study of the solidification of these alloys and the use of closely controlled temperatures.

Details of the liquation process cannot be given here; it will suffice to say that in the first stage of natural liquation most of the copper is separated by crystallizing out as Cu_3Sn. The liquid is drained off and the antimony and the balance of the copper are eliminated by liquation and chemical treatment with metallic chlorides, leaving a tin-lead alloy, suitable for use in solders. The solid residue from the first operation is calcined and leached with sulphuric acid; the sulphates are then marketed as salts or they may be reduced to metal.

Zinc Alloys — Zinc alloy applications are well known in the United States where most of the developmental work was done. Much scientific and technical study was given to the subject in Germany in the 1930's in preparation for the eventual copper shortages which were expected to result from the coming war. As with the other metals discussed above, we can do no more than review the salient points concerning the substitution of zinc alloys for copper alloys.

Zinc has properties quite different from those of copper; it has a low melting point, and consequently a high coefficient of expansion and a high creep rate at room temperatures; it has a hexagonal crystal and consequently it is difficult to work and is subject to marked directional properties resulting from preferred orientation. Finally, as is well known, the dimensional stability and intercrystalline corrosion resistance are satisfactory only if the zinc is extra pure or contains slight amounts of magnesium.

In practically all of its applications, it is best that zinc alloys be protected against corrosion by nickel or chromium plating or by some chemical treatment.

On the other hand, its low melting point and its castability make the metal particularly well adapted to die casting and pressure casting, permitting precise dimensions on thin sections and complicated shapes. Even before the war, these alloys were well known in France for fabricating automobile parts such as carburetors.

To much of the industry, however, zinc alloys were a novelty, especially the semifinished products such as sheet, rod and tube. Certain precautions were necessary in the use of these alloys and the Ministry of Industrial Production created a technical organization under the name of the "Committee of Organization and Control for the Use of Zinc Alloys" whose duties were not only to counsel and set up technical control of industry but also to avoid German interference in these endeavors.

Standardized Wartime Zinc Alloys*

Composition	Zamak Alloys (With Aluminum)				AZ Alloys		
	Zamak 2	Zamak 5	Zamak β	Zamak λ	AZ-1	AZ-2	AZ-3
Al	4	4	10	0.8	—	0 to 0.1	0 to 0.2
Cu	2.5 to 3.0	0.5 to 1.0	0.6 to 1.0	0.4	1.0	2.0	3.0 to 5.0
Mg	0.2 to 0.5	0.2 to 0.5	0.2 to 0.5	0 to 0.2	—	0 to 0.3	—
Others	—	—	—	—	Mn 0 to 0.5	—	Si 0.1 to 0.3 Mn 0.1 to 0.3 Pb 0.5 to 0.8 Te 0 to 0.1
Used as†	Cast	Cast or wrought	Wrought	Cast or wire drawn	Wrought	Cast or wrought	Wrought

*Based on zinc 99.993% pure. †"Wrought" includes most forms of mechanical working, such as wire drawing, die pressing, rolling and extrusion.

First the committee cut down the long list of zinc alloys then manufactured, and limited production to seven alloys shown in the adjoining table. These were enough to fill all requirements; even this number was reduced after some experience, and finally the types were standardized.

At the outset it should be mentioned that, during the war, plating of fabricated parts was practically impossible because of the scarcity of nickel and chromium in France. Furthermore, the quantity of zinc alloys available in France for replacing brass and bronze was limited and it was necessary, therefore, to avoid many interesting applications of these alloys which were not absolutely necessary to the economy of the country.

Pressure Castings — This is the field for which zinc alloys are best suited and one in which they are not, properly speaking, substitution alloys. Before the war, the automobile industry was the largest consumer of zinc die castings. After 1941, the fittings industry, hardware trade, locksmithing trade and clock manufacturers absorbed almost all die cast zinc alloys.

It is expected that the advances made by these alloys at the expense of brass in these fields will be retained in the future, for the use of Zamak 5 is being increased in place of Zamak 2.

Gravity Castings — The most important applications of gravity castings have been in the plumbing and fittings trade, using Zamak 5. Some corrosion failures were encountered in water line fittings, especially when in contact with nickel or brass. These alloys were not used for hot water. The prohibitions against nickel plating interfered with their application to overflow pipes, drain pipes and syphons.

On the other hand, excellent results were obtained in applying these alloys to gas fittings. Zamak 5 was also used with great success for both building trade hardware and drawer pulls and other furniture hardware.

Lastly, a very interesting application was the use of Zamak 5 or Zamak β for bearings. Good results were also obtained in bearings for street cars and mine cars.

Semifinished Products — Zamak 5 and 2 were practically the only alloys used to replace free-cutting brass. AZ-3 alloy, which gave a good fine chip and which was well suited to automatic screw machine operation, was not used much because it contained lead and bismuth, which were troublesome impurities in the scrap reused by plants having their own zinc foundry.

Screw machine parts were used mostly for screws, cocks, small electric parts, and automobile or bicycle tire valves. The production rates expected with brass could not be attained with Zamak alloy rod, drilling and tapping of this alloy being especially difficult.

Attempts were likewise made to replace brass with Zamak 5 for stamped or forged parts; thus this alloy was used to make automobile valves which could not be made of iron or duralumin. It is expected, however, that in the future brass will retain its advantage because of the higher cost of hand labor required for the zinc alloys. It would seem that die casting is the more likely field for Zamak alloys.

Zamak 5, AZ-1, AZ-2, and zinc strip were used in making small electric parts, clock parts, and zippers. Some trouble was encountered with fasteners, since the zinc did not adapt itself to dimensional changes of the fabric arising from temperature and humidity variations.

Bent and formed parts for electrical apparatus gave good results when made in zinc, if they were not subjected to large stresses in service. Its low resistance to plastic flow prevented the fabrication of lighting equipment or parts subjected to high temperatures. However zinc sheet was used for lamp sockets. (Once, in 1942, the Germans planned a large social gathering in a hall where such equipment was installed. To brighten up the premises, 200-watt bulbs were substituted for 60-watt bulbs in all sockets. During the course of the evening, all of the bulbs fell out and crashed; the zinc sockets opened up at the higher temperature under the simple weight of the bulbs they were supporting.)

Low resistance to plastic deformation also prevented the substitution of Zamak λ wires for copper or aluminum.

Applications of zinc alloys in war material will not be listed here because they will be of less interest in the future.

To sum up, zinc alloys are best substituted in the chill-cast condition. The hardware trade, locksmithing, and fittings manufacturers will undoubtedly continue to use these alloys for many applications, replacing prewar brass. Lastly, the clock, household appliances, and costume jewelry manufacturers will use these alloys when there is a supply of nickel or chromium for plating.

Conclusions

The most important work done on substitute metals that will have some permanent value in future applications includes the substitute steels, die cast zinc alloys, new compositions of babbitts and solders, the art of aluminum scrap recovery, repair and resurfacing by fusion welding, as well as specific applications that will be modified and improved in the future.

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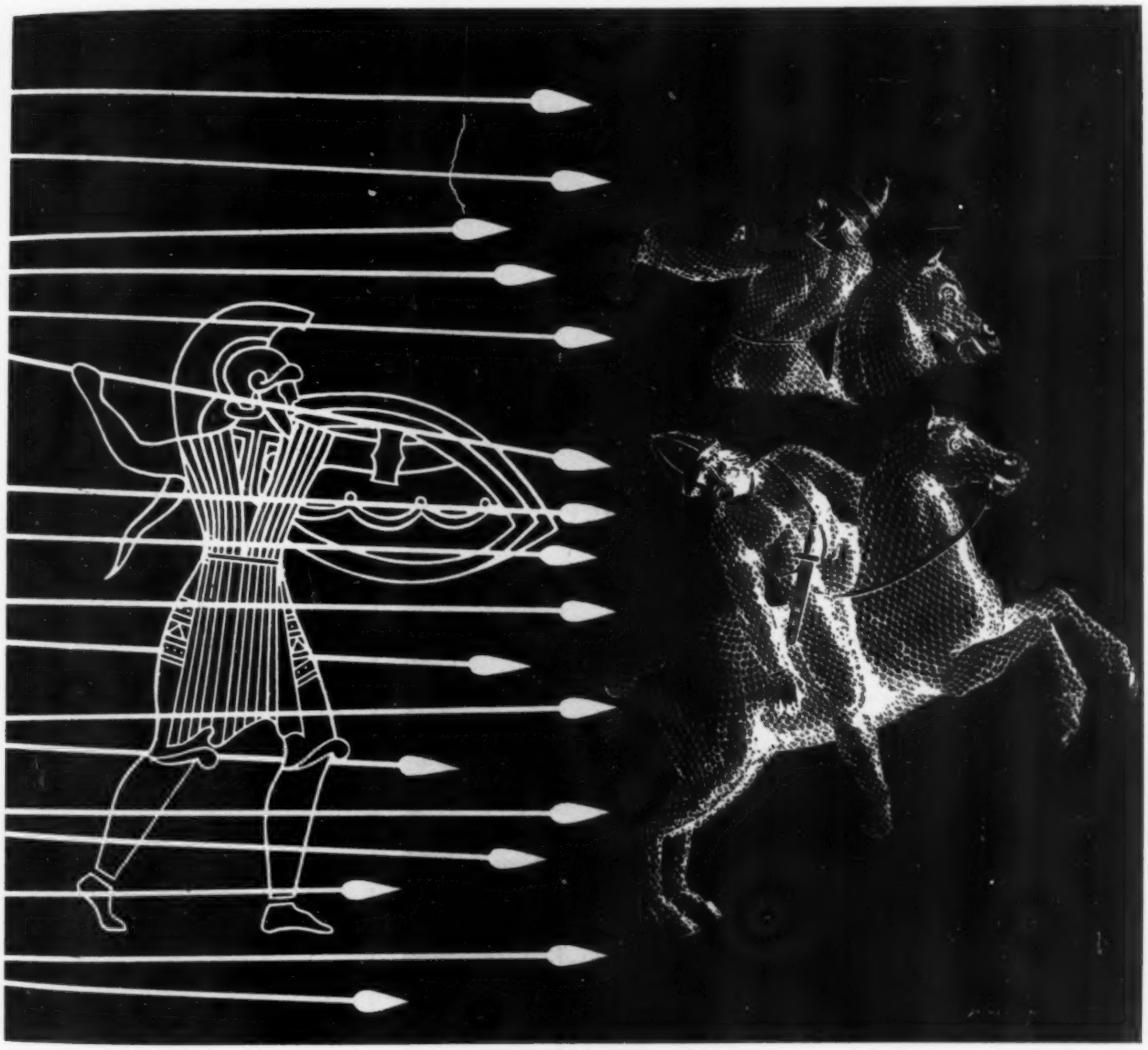

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Personals

R. E. Wagenhals, formerly quality control engineer, has been appointed director of quality control for all bearing divisions of the Timken Roller Bearing Co., Canton, Ohio.

Raymond E. Paddock, formerly vice-president in charge of manufacturing and engineering, Steel Materials, Inc., Cincinnati, Ohio, is now works manager, Hunt Spiller Mfg. Co., Inc., Boston.

Drexel Institute of Technology, Philadelphia, has introduced a new series of courses in metallurgical engineering under the direction of Prof. A. W. Grosvenor. An advisory committee on metallurgical engineering has also been appointed consisting of G. H. Clamer, president of the Ajax Metal Co.; William J. Diederichs, metallurgist, Autocar Co.; Francis B. Foley, superintendent of research, Midvale Co.; Clyde B. Jenni, metallurgist, General Steel Casting Corp.; and Joseph Winlock, chief metallurgist, Edward G. Budd Mfg. Co.

Walter G. Patton, formerly with Climax Molybdenum Co. of Michigan, is now Detroit editor of *The Iron Age.*

George K. Dreher has resigned as vice-president in charge of manufacturing and works manager of Ampco Metal, Inc., Milwaukee, to become vice-president and general manager of the Rogers Pattern & Foundry Co., Los Angeles.

Robert A. Peterson has resigned as division superintendent of hot mills for American Steel & Wire Co., Cuyahoga Works, Cleveland, to open his own hot mill consulting service.

R. Smoluchowski, formerly research physicist with the General Electric Co. in Schenectady, is now associate professor in the department of metallurgical engineering at Carnegie Institute of Technology and a member of the Metals Research Laboratory.

Robert C. Kingsbury is now factory representative for Dodge Mfg. Corp., Mishawaka, Ind., covering southern California, Arizona, New Mexico, Colorado and Utah, with headquarters in Los Angeles.

Fred R. Sweet has been appointed staff metallurgist of the research and development division of New Mexico School of Mines in Albuquerque.

Edwin W. Olsen, formerly with Campbell, Wyant & Cannon Foundries, Muskegon, Mich., has been appointed foundry superintendent at the Weber Engine Co., Kansas City, Mo.

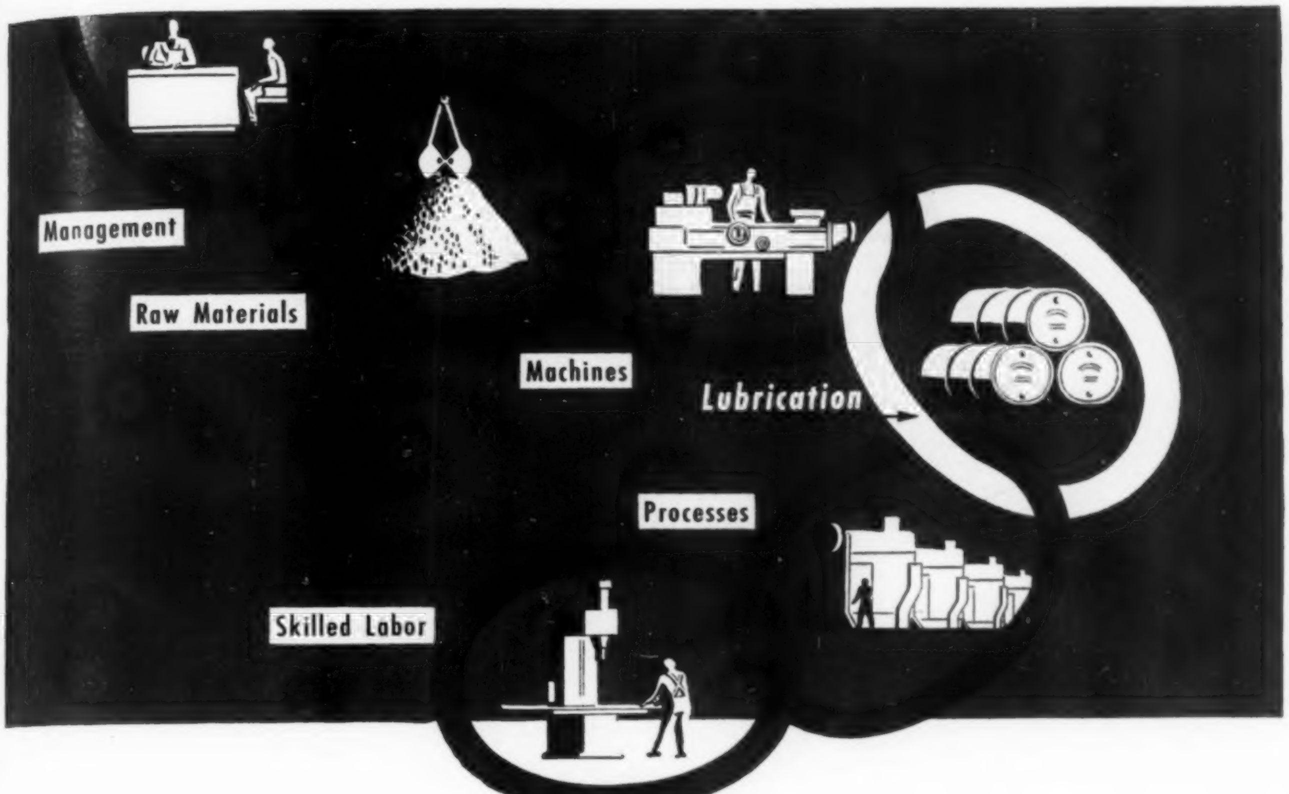
Elwood Cramer has taken the position of foundry manager for the Bolen Machine Works in Grand Junction, Colo.

Charles T. Post has been transferred from regional news and technical editor, *The Iron Age*, Chicago, to manager of reader service in the New York office.

Frank G. Foote is now associate professor of metallurgy in the School of Mines of Columbia University.

Upon release from the Navy, Sydney M. Swartz has become associated with the Naval Research Laboratory in Washington, D. C., as an associate metallurgist.

Ray A. Zimmerly has been appointed spectrographic foreman of a new laboratory of Columbia Steel Co., Pittsburg, Calif.



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Personals

HARRY W. PETERSON ⊕, formerly with Arms-Franklin Corp., Youngstown, Ohio, is now development mechanical engineer with Ideal Roller & Mfg. Co., Chicago.

After serving as assistant chief metallurgist for eight years at Bell & Howell, as chief metallurgist at Zenith Radio for three years, and assistant to factory manager at Webster-Chicago Corp., JAMES F. ENGLE ⊕ has opened his own business known as the Westwood Water Distributing Co.

DONALD E. THOMAS ⊕ is returning to Carnegie Institute of Technology for graduate work in the department of metallurgy after four years in Naval Ordnance, latterly as metallurgist at the armor and projectile laboratory at the U. S. Naval Proving Ground, Dahlgren, Va.

C. L. HIBERT ⊕, formerly employed by Hanlon & Wilson, Wilkinsburg, Pa., has returned to the West Coast as process engineer for the Consolidated Aircraft Corp. of San Diego.

J. H. HOLLOMON ⊕ is now research metallurgist at General Electric Co., Schenectady, N. Y. Before leaving Watertown Arsenal he was promoted to the rank of major and awarded the Legion of Merit for his work at the Arsenal laboratory.

FRANK W. FAERY ⊕ has been appointed district manager of the Alloy Casting Co., Champaign, Ill. He was sales engineer for the Park Chemical Co. for 19 years, and during the four war years he operated and managed his own heat treating plant.

OWEN E. LENTZ ⊕ is now with the Machine Screw Product Co., Wichita, Kan., as a consultant in metallurgical work and foreman of the heat treating department.

DAVIS HUTCHINSON ⊕ is now with Boeing Aircraft Co., Seattle, Wash., as an engineer in the special tools group of the service department.

COMDR. P. E. PAGE ⊕ has been transferred from officer in charge, metallurgical and testing section, U. S. Naval Gun Factory, Washington, D .C., to administration inspection officer in the Office of Supervising Inspector of Naval Material, Pittsburgh.

Personals

C. E. HATHAWAY ⊕, formerly chief metallurgist with Waukesha Foundry, Wis., and chemical process engineer with Globe Union Co., Milwaukee, is now with United States Rubber Co., Mishawaka, Ind., as chemical engineer in rubber development.

After 17 years with the Bureau of Mines, in which he rose from chief engineer of the metallurgical division to assistant director, R. S. DEAN ⊕ is leaving Government service to re-enter private business. Dr. Dean will continue professional work in Washington, where he has commissions for research and development in electrometallurgy and alloys.

Transferred by the Navy Department: COMDR. R. H. LAMBERT ⊕, from officer in charge, metallurgical and testing section, U. S. Naval Gun Factory, to officer in charge, welding, casting and forging section of the Bureau of Ships, Washington, D. C.

E. H. WHEELER ⊕ has been appointed factory representative for LaPlant-Choate Co., Inc., in charge of subcontracting work in the Yuba Mfg. Co. plant in Benicia, Calif.

Reorganization of the Tocco induction heating division of Ohio Crankshaft Co., Cleveland, involves appointment of HARRY L. KELLER ⊕, formerly automotive production engineer in charge of engineering standards at Buick Motors Corp., as head of the new Tocco commercial engineering department. HARRY B. OSBORN, JR. ⊕, formerly research and development engineer, has been promoted to sales manager of the Tocco division and JOHN T. VAUGHN to research and development engineer.

Promoted by Chrysler Corp.: EDWARD H. STILWELL ⊕, to chief contact metallurgist for the Dodge main plant, Dodge Forge, and Newcastle plants.

EDWARD G. MARTIN ⊕, formerly staff member and engineering consultant, radiation laboratory, Massachusetts Institute of Technology, and JOHN F. HUBBARD, recently of U.S.N.R. and radiation laboratory, announce the formation of the Martin-Hubbard Corp., Boston, engineering consultants for the design and construction of scientific instruments.

Personals

RICHARD L. HOFF has left the Manhattan Project in Oak Ridge, Tenn., to become a research assistant in metallurgy at Massachusetts Institute of Technology and to pursue studies leading to the doctor of science degree.

BERNARD P. FAAS has accepted a position as metallurgical engineer with the Woolridge Mfg. Co., Sunnyvale, Calif.

CLYDE WILLIAMS, director of Battelle Memorial Institute, Columbus, Ohio, has been presented the honorary degree of doctor of science by the University of Utah, Salt Lake City.

R. BUECHTING has been promoted by Philadelphia Steel & Wire Corp. to general superintendent.

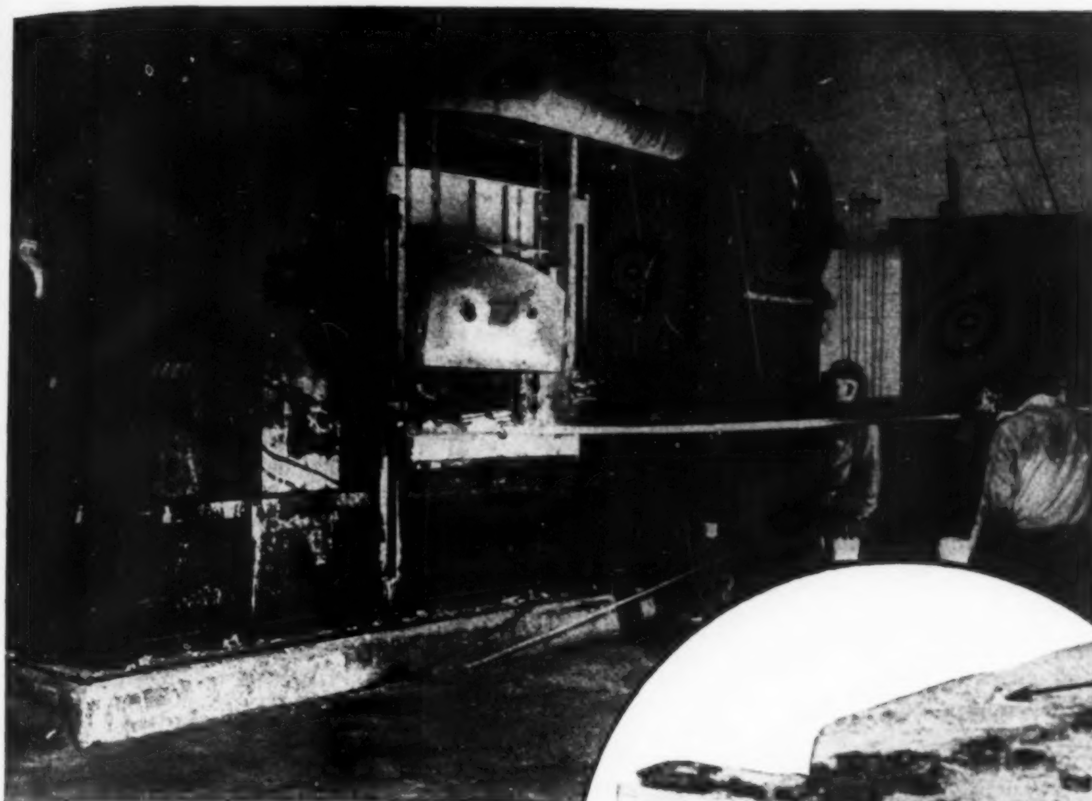
While retaining his connection with Holcroft Co. of Detroit as consulting metallurgist, J. A. DOW has organized the Dow Furnace Co., of which he is president, to build a noncompetitive line of batch-type heat treating furnaces.

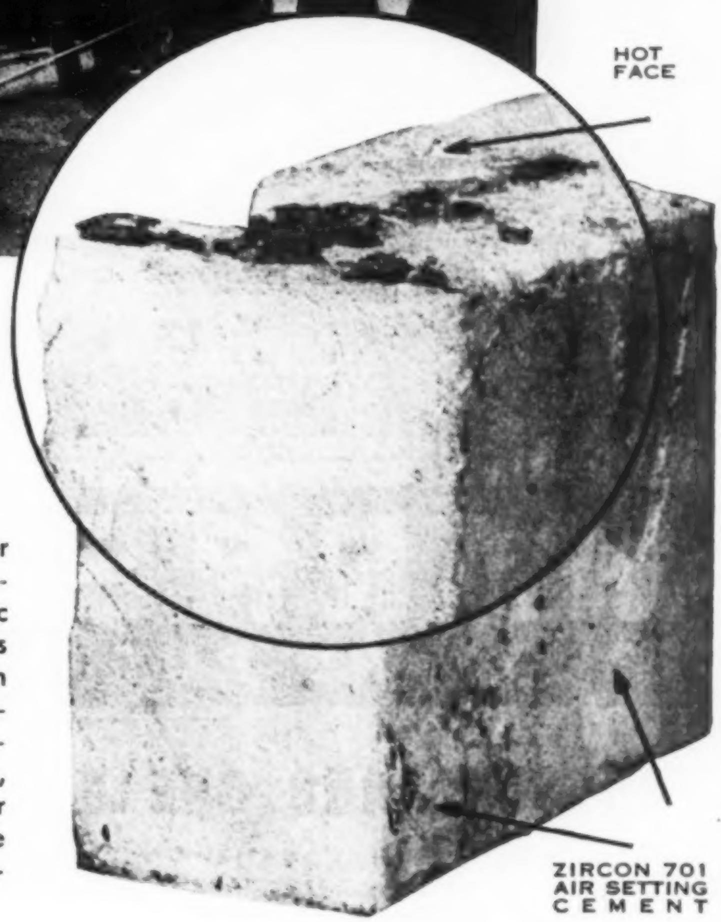
WALTER K. GRAHAM has been appointed executive administrator of a newly opened office of the A. O. Smith Corp., Milwaukee, in Atlanta, Ga., serving the states of Georgia, North and South Carolina, Florida, Alabama, Mississippi and Tennessee.

Jackson Associates, manufacturers' representatives and engineers, with offices in Philadelphia, New York, Newark and Baltimore, announce that ARTHUR R. DIAMOND has joined their organization as special representative in Philadelphia.

Three district sales engineers have been appointed by the Timken Roller Bearing Co., Steel and Tube Division: SHERMAN R. LYLE, formerly in the Timken steel sales department, for the Cleveland district; WILLIAM EARLE BRYDEN, formerly with Timken and during the war with the U.S.N.R., for the Chicago district; and ALFRED J. KINNUCAN, formerly on active duty with the U. S. Navy, for the New York district.

WILLIAM J. GAMBLE and his son ENSIGN ROBERT N. GAMBLE, recently released from active Navy duty, announce their partnership as manufacturers' representatives operating from Buffalo, N. Y., under the name Gamble and Gamble.





TAYLOR ZIRCON

for the Aluminum Industry

Zircon Refractories have the peculiar property of not being readily "wet" by aluminum metal, dross, or oxide. The true specific gravity of Taylor Zircon is 4.46, so any spalls or small particles of Zircon will not float in aluminum or the common alloys. The experience of the past three years has shown conclusively that Taylor Zircon brick hearths, bonded with our No. 701 Zircon Cement offer these advantages over hearths built of fire clay, super duty, high alumina or silicon-carbide brick:

- Cleaner Metal
- Increased Production
- Lower Hearth Costs per ton of metal.

PROPERTIES OF TAYLOR ZIRCON REFRACTORIES AND OTHER PERTINENT DATA ARE GIVEN IN BULLETIN No. 200. WRITE FOR YOUR COPY.

CHAS. TAYLOR SONS Co.

MANUFACTURERS OF REFRACTORIES • CINCINNATI • OHIO • U. S. A.

EXCLUSIVE CANADIAN REPRESENTATIVES: Refractories Engineering and Supplies, Ltd., Hamilton, Ontario, and Montreal, Quebec

Molten Steel Temperatures*

DETAILED drawings are given for a quick immersion type of thermocouple which is supported on an inclined arm, mounted like a small jib crane on a buckstay near the center line of the open-hearth's back wall, and hinged at the attachment so when in use the arm is perpendicular to the wall, but when not in use it is swung back against the bindings, out of the way of the charging machine and other operations. The thermocouple wires are contained in a straight, rigid tube some 11 ft. long, its outer end being carried by a slide running on the inclined arm, the inner or lower end (when retracted) resting on a roller near the buckstay attachment. A suitably inclined hole is opened through the furnace wall so the thermocouple assembly can be run forward and downward until its lower end is immersed about 9 in. into the steel bath at a position about midway between the back wall and the center of the furnace. These in-and-out motions are controlled by counterweight and hand lever so they are easily manipulated by a single workman.

The pyrometer is of platinum wire, threaded through pipe stem insulators contained in ¼-in. iron pipe and this in turn is surrounded by a 13/16-in. o.d. heat resisting steel tube. The fire end of this outer tube is threaded and flanged. Against the flange abuts a series of graphite protective sleeves 1¾ in. o.d.; joints between the sleeves are sealed with plumbago paste, and against the upper end presses a compression spring, held by sleeve and set screw, to allow for thermal expansion.

Over the threaded hot end of the protection tube is screwed a steel block, 6 in. long and 1¾ in. o.d., drilled centrally to pass the pipe stems and thermocouple wires, and counterbored to hold a tapered plug made of a mixture of graphite and clay. This plug fixes a bare silica sheath, protruding about 2½ in., which contains the twisted ends of the platinum wires. A thin coating of slag adheres to the steel plug as it dips into the furnace bath and protects the plug as long as it is necessary *(Cont. on p. 506)*

*"Improvement in Design of Immersion Pyrometers for Liquid Steel Temperatures", by D. Manterfield and J. R. Thurston, advance copy of paper for Iron & Steel Institute, June, 1946.

Steel Temperatures

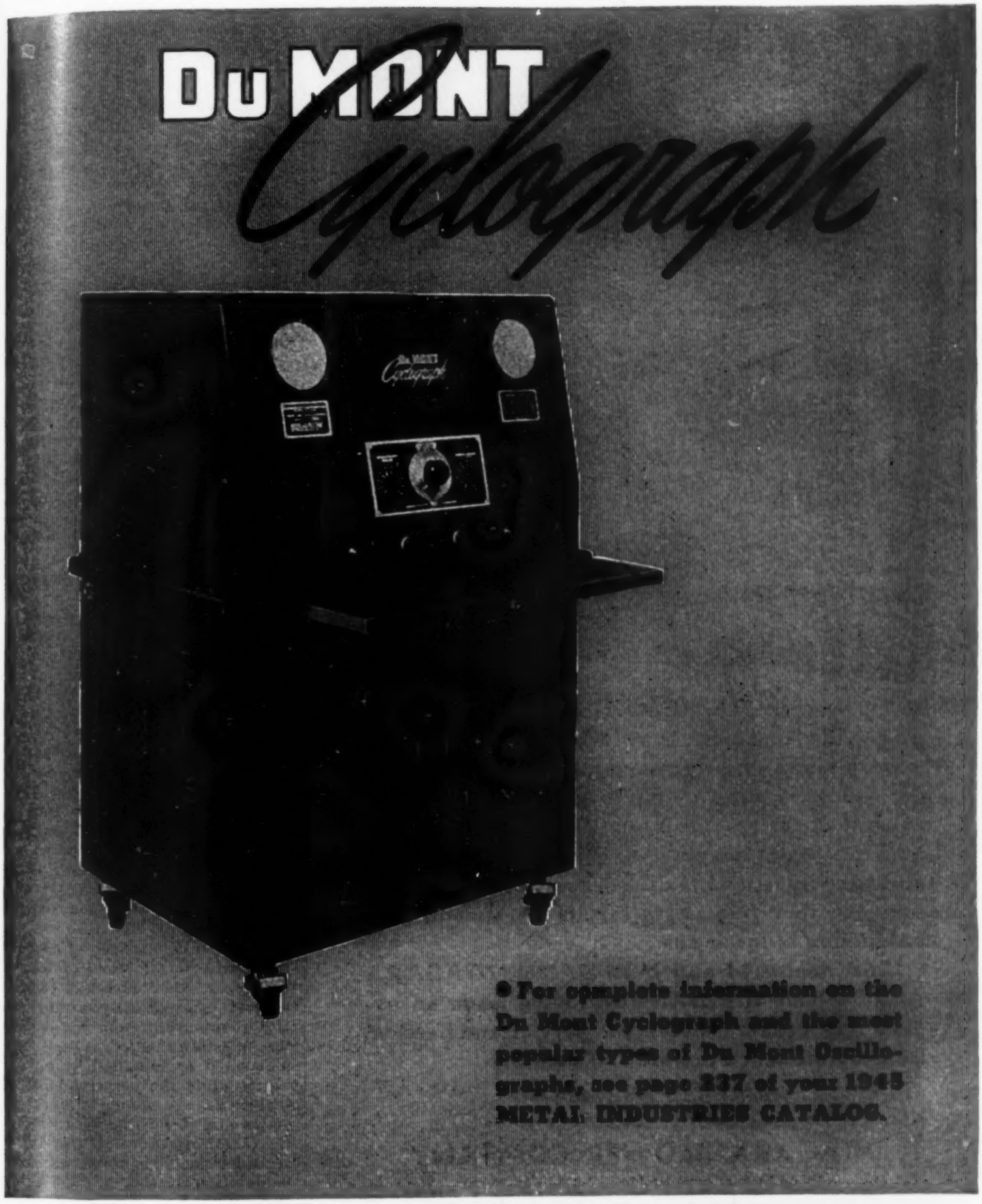
(Cont. from p. 504) to take the temperature. Steel plugs have been used for 750 immersions; they are better than carbon end protection plugs because the latter produce a little CO when hot, which embrittles the pyrometer wires.

The outer or upper end of the heat resisting steel tube is screwed into a terminal box within which are made the necessary connections to jacks or terminals for quick attachment for potentiometer or other temperature indicating device.

Machinability

A DAY-LONG conference on machinability was held by the British Institution of Mechanical Engineers in May, in which 14 papers were presented. They were divided into four main headings (physical basis, testing methods, cutting conditions, economics of production) and the extensive discussion reported in four issues of *Engineering* starting June 7.

The lack of an acceptable definition of "machinability" was mentioned frequently. Cogent arguments were advanced for the idea that "machinability" should apply to the material being cut, and exclude factors having to do with the tool, lubricant and nature of the operation. This would require a standardized tool and one of diamond or carbide practically impervious to wear, at least resistant enough that its shape and sharpness would not change during the test. Such a course, would, of course, render obsolete the oft-used test for machinability which refers it to the life of the tool to breakdown, or another criterion that attempts to relate machinability to the power consumption of the machine tool. Many references to the friction between chip and tool (rather than the temperature reached at the tool tip) indicated that this criterion was thought to be a valid measure of the machinability of metal, but it was also pointed out that on the one hand uniform supply of cutting fluid to the working point of the tool would be hard to insure because it is doubtful even that any gap exists there, while on the other hand dry cutting would be so different in nature from most machine shop operations that dry tests had doubtful value. *(Continued on page 508)*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Machinability

(Continued from page 506)

An interesting suggestion was that the lead particles in leaded brass or steel was an internal lubricant, and during cutting was smeared out in a layer a few atoms thick along the rubbing surface, and so the same inherent properties of lead were utilized in machining as in the antifriction properties of lead bearings. This theory was also extended to the possibility that high sulphur compounds in machinable metal acted much as did sulphurized cutting compounds. According to the American investigators Ernst and Merchant (who, by the way, were continuously quoted in *Engineering's* report) the active sulphur reacts with the nascent clean surface as it is laid bare at the instant of cutting, and forms sulphides under the conditions of pressure and temperature present, and these sulphides reduce the adhesion of tool to chip.

W. B. Wragge, long a student of the problem of machinability as concerns the material being cut, said that in his experience any one of a dozen techniques that had received attention in the past 20 years would (if properly conducted and interpreted) be used to assess the result of changing any one of a dozen conditions — within rather narrow limits. None of them, however, had sufficient generality. A recently proposed criterion for machinability is the "plasticity ratio" derived from a simple test where the true stress is plotted against the true strain. However, a comparison of over 100 recorded determinations of machinability by other currently popular methods showed only a very general relationship. In his opinion the "plasticity ratio" must be supplemented or modified by a value representing the abrasive effect of inclusions. A simple stress-strain curve and a turning test wherein the temperature of the tip is recorded should give the necessary data for derivation of such a criterion.

Other speakers believed a single index of machinability related to the material was elusive, because of variability in the reaction of a single metal in different machining operations. For example, a completely spheroidized steel was best for machining and finishing balls, but this same steel sawed and drilled better if *(Cont. on p. 510)*

Machinability

(From p. 508) the microstructure retained a little pearlite. Likewise, a tough continuous chip which was desirable for turning operations would tend to fill and seize the flutes of a drill or lodge between saw teeth. Again, two different types of steel heat treated to very similar physical properties and microstructure could produce about the same tool wear when cut under identical conditions but have a very different quality of surface — the mean depth of irregularities being on the order of 2 to 1.

Materials for Jet Engines

IN A PAIR of articles in *The Iron Age* for July 25 and Aug. 1 entitled "Metallurgical Development of Materials for Turbosuperchargers and Aircraft Gas Turbines", W. L. Badger, who is in charge of the metallurgical section of General Electric's laboratory at Lynn, Mass., noted that the temperature requirements of the wheels and buckets in the modern supercharger are more severe than in the gas turbine for aircraft (1500° F. in leaded gas engine exhaust versus 1350° F. in lead-free gases) but the sizes are much greater in the gas turbine (a 10-in. wheel made from a 35 lb. forging versus a 30-in. wheel weighing 400 lb.). He also notes that American engineers have had about 28 years to develop the supercharger, whereas they began work on the turbojet units less than five years ago.

In the nearly 30 years of development the supercharger wheels were made of S.A.E. 2335, S.A.E. 6150, Silcrome No. 1, 17-W (12 Cr, 19 Ni, 2¼ W, 1.0 Mo), γCb (15 Cr, 25 Ni, 4 Mo, 1 Si, 2 Cb) and 16-25-6★ which is the present alloy. Stresses at the rim demand a high rupture strength at 1300° F.; at the center the temperature is 600° F. and the yield strength must be at least 80,000 psi. Forgeability, machinability and weldability are required. Buckets are chosen largely on rupture strength at 1500° F. Difficulty with machining the forgings has led to the use of precision castings (they weigh about 0.02 lb. each). *(To p. 512)*

★See *Metal Progress,* July 1946, page 107 e.s., for properties of this and other alloys mentioned.

ANOTHER

DREVER VERTICAL STRIP ANNEALING FURNACE

Featuring quality and production on the following metals:

ALLOYS

Beryllium Copper
Cupro Nickel
Nickel Silver
Phosphor Bronze
Red Brass

BI-METALS

[illegible] Steel-Everdur
Nickel Steel-High Nickel
[illegible] Chrome Alloy
[illegible]-Nickel Chrome
Alloys and others

PRECIOUS METALS

OUTSTANDING for its

- **Versatility and flexibility of production.**
- **High quality bright anneal or open anneal.**
- **Minimum floor and storage space.**
- **Economical, efficient operation.**

Designed to handle the variety of non-ferrous metals listed here, in a wide range of gauges. In all cases, even the Bi-Metals, mirrorlike finishes are being obtained—without subsequent pickling when using the Drever Ammonia Dissociator as the protective furnace atmosphere. Quality standardization is obtained through the ability to repeat time-temperature cycles with a high degree of accuracy.

The related handling equipment such as the take-up and pay-off mechanism has been perfected for quick, easy production with minimum handling of material and low labor cost during processing. Capacities range from a few pounds to several tons per hour, depending on material size.

The Drever furnace design has been standardized and is readily adapted to many production lines in any size or capacity range. We will be pleased to discuss with you the inherent advantages of this furnace as they may apply to your specific requirements.

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CONTINUOUS FURNACE LINES • HEAT TREATING FURNACES • ATMOSPHERE EQUIPMENT

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Jet Engines

(Cont. from p. 510) Bucket materials used in succession during the development have been S.A.E. 6140, Silcrome No. 1, KE-965 (13 Cr, 13 Ni, 3 W, 1½ Si), 17-W and Vitallium. Buckets are welded to wheels with KA-2 S (Mo) weld rod.

The first nozzleboxes on turbosuperchargers were made of calorized steel sheet, next of nickel plated sheet, then a weldable Ni-Cr-Mo austenitic steel sheet. Diaphragms are now centrifugally cast to size of a 25 Cr, 20 Ni, 1½ Si alloy. Cooling caps are of stabilized 18-8 stainless.

Permanent mold casings for the blower end were first made of Al-Si-Mg alloy but to improve the machinability the alloy was changed to Al-Cu-Si-Mg (Alloy 35S). The impeller requires light weight, high bursting speed, low stretch at tip speed in excess of 2000 ft. per sec., high endurance limit, ability to redistribute localized stress, machinability, high stress-rupture properties, freedom from stress-corrosion and good forgeability — truly a formidable combination. Alloy 25S-T has been used for impellers since 1927 and has given satisfactory life in aircraft service.

Turbojets — Bucket wheels in the large units are a composite of S.A.E. 4340 for shaft and center and 16-25-6 for the wheel rim, the two flash welded together, or fusion welded with 29-9 Cr-Ni weld rod. The assembly is then strain relieved below the tempering temperature of the 4340. Inspection includes X-rays and supersonic waves for internal cracks and Zyglo for surface checks.

Buckets for the smaller sizes of wheels are made of spheroidized Hastelloy B (65 Ni, 28 Mo, 6 Fe, 0.35 V, 0.75 Mn, 0.75 Si) and of as-cast Vitallium (65 Co, 27 Cr, 5 Mo, 2 Ni, 1 Fe) for the larger wheels. These "large" (0.85 lb.) castings are subject to large and variable grain size and chromium oxide inclusions, both of which are thought to have caused some fatigue failures. Fatigue is a matter of more concern than stress-rupture or corrosion resistance in buckets on the large wheels (working temperature 1350° F.).

Sheet metal parts in gas turbines (except liners) are made of welded stainless steel Type 347. Some diaphragms have been fabricated of 25-20 drop forged blades welded to a *(Cont. on p. 514)*

Jet Engines

(Starts p. 510) punched inner and outer ring assembly. Combustion chamber liners are likely to be corroded by lead compounds from high octane gasoline used occasionally for fuel; materials for this are Inconel or 25-20 with 2% Si. Design insuring uniform heating is quite as effective as expensive use of strategic alloys in licking difficult problems in this equipment.

Radial flow compressors require impellers whose tip speed is approximately 50% higher than the speed of sound. They are machined from 25S-T aluminum alloy forgings, the largest forging weighing 900 lb. Compressor casings and accessories are made of Dowmetal C and H magnesium castings (AM 260 and AM 265), solution heated and stabilized at 500° F. to avoid minor distortion by service temperatures and loads.

Brittle Ships*

BREAK-UP of the tanker Schenectady in 1943, an American all-welded ship, while tied up in a fitting basin, led to a careful study of the methods of design and construction of welded merchant vessels by the British Admiralty, although English shipbuilders used welding to a far less extent than Americans, and the trouble with ship's hulls built in wartime were far less serious. It was supposed that reliance on more conventional methods of construction (use of a considerable number of riveted seams) and reliance on more skilled personnel would avoid trouble, but these early expectations have now been discounted. Full interchange of information with American investigators has been of great help.

It should be said at the outset that the ships that got into trouble (10 welded ships are known to have broken in two due to causes other than war, collision or stranding, as well as more numerous failures of less than disastrous extent) were built of steel which with very rare exceptions passed the specifications thoroughly satisfactory for riveted hulls, and *(Cont. on p. 516)*

*From "The Work of the Admiralty Ship Welding Committee", by A. L. Clark and G. M. Boyd, paper read before the British Institution of Naval Architects and reprinted in *Engineering* for May 31 and June 7, 1946, pages 509 and 549.

YOU SOLVE 4 PROBLEMS

when you switch to

INCONEL* THERMOCOUPLE PROTECTION TUBES

HIGH TEMPERATURES!

Inconel is ***thermally durable***. Hundreds of high-temperature applications in many fields have demonstrated the heat resistance of this 80% Nickel – 14% Chromium alloy. You can use Inconel thermocouple protection tubes up to 2200° F. in sulfur-free atmospheres.

And at ***any*** temperature, you'll find the thinner walls of close-grained Inconel tubes a big help where you need ***quick, accurate response*** to temperature changes.

CORROSION!

Inconel is ***corrosion-resisting***. Because Inconel combines unmatched thermal endurance with all-'round corrosion resistance, you can use Inconel protection tubes to guard thermocouples against chemical attack by carburizing vapors and gases . . . nitriding atmospheres . . . hydrogen-nitrogen atmospheres . . . fused salt baths.

The greater impermeability of ***seamless, drawn*** Inconel tubes also means better protection of thermocouples from harmful gases.

MECHANICAL SHOCK!

Inconel is ***strong*** and ***tough***. And, it maintains its strength and toughness at high temperatures. In many jobs *(for example, forging furnaces)*, thermocouple protection tubes have to take bumps and jolts during charging and discharging. These are the jobs where use of Inconel pays an ***extra*** dividend. As a matter of fact, its high hot-strength frequently makes Inconel the choice even where excessive corrosion or high temperature is not a problem.

REDUCING AND OXIDIZING ATMOSPHERES!

Inconel has met the problem created by increased use of ***reducing*** atmospheres in bright annealing, nitriding, oxide reduction, and similar operations. Inconel gives long service in these processes because it resists the embrittling effects of hydrogen-nitrogen atmospheres.

Or if your operation is carried out in an ***oxidizing*** atmosphere, you can count on Inconel tubes here, too. For Inconel resists scaling . . . ***even at high heat.***

Prevent operating interruptions caused by thermocouple protection tubes that can't "take it."

Standardize on Inconel tubes wherever possible! For most jobs their longer life makes the cost ***actually less*** than the tubes you are now using.

Seamless, drawn Inconel protection tubes, with one end closed and the other end threaded, are available in standard IPS diameters. ***Your regular supplier or instrument manufacturer can furnish any size or length with either standard or extra-heavy wall thickness.***

*Reg. U. S. Pat. Off.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 Wall St., New York 5, N. Y.

INCONEL – for long life at high temperatures

(80 NICKEL-14 CHROMIUM)

Brittle Ships

(From p. 514) that there was no reduction in sections in the welded designs. It should be remembered, however, that ship steel specifications call for tensile and bend tests. Metallurgists now agree that the welding procedure does not change the inherent properties of the steel, since most of the fractures progressed as if the welds did not exist. However, a fairly common characteristic of the samples taken from fractured plate is "notch brittleness" at temperatures well within the service range, whereas prewar ship steel made in England normally retains its toughness, even when notched, to temperatures rarely encountered in the service life of a ship. In spite of much study, the steelmaking conditions responsible for the two varieties of plate (of indistinguishable chemistry) are yet unknown; likewise there is as yet no agreement as to a simple routine test by which notch brittleness can be assessed.

There is much to be said for the view that brittleness in a rigid structure, like an all-welded ship, is due to locked-up or residual stresses known to be induced by welding. It has proven very difficult to evaluate these stresses. Two methods have been used — one, the attachment of strain gages, the trepanning of the plate under the attachment, and recording changes in dimension of the freed plug, and two, the measurement of atomic spacing by X-ray diffraction methods. The first mentioned is far more accurate; both suffer from the fact that they give little information about strains over the yield point. As a result of such studies, however, it may be concluded that locked-up stresses cannot be avoided by any trick combination of welding procedure, sequence or restraint. Other information convinced the authors that if both base material and weld *behave in a normal ductile manner*, locked-up stresses due to welding do not impair the strength of structures.

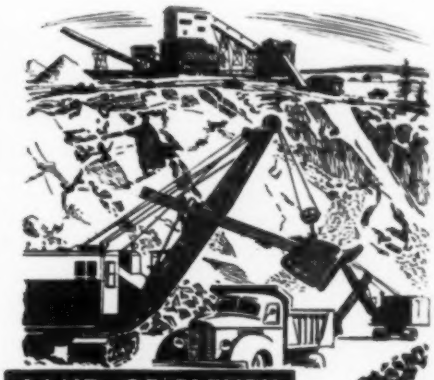
While good workmanship by welders is as important as by any other artisan, the authors are of the opinion that weld defects are not the culprit. Weld defects which have been found associated with fractures are usually too small to account for the suddenness and extensiveness of the failures. Likewise riveted ships have remained in satisfactory service with quite large cracks in *(Cont. on p. 518)*

ONE OF A SERIES OF STORIES ABOUT ALLOYING METALS . . . WHERE THEY COME FROM AND HOW THEY ARE USED

THE STORY OF SILICON

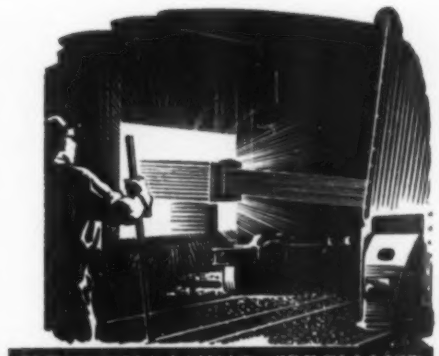
EARLY START IN LIFE

Way back in the Stone Age are found the first uses of silicon—in the tools and weapons used by prehistoric man. These were made of flint, which is almost pure silica, and in silica many centuries later the Swedish chemist Berzelius discovered the element silicon. He produced the world's first ferrosilicon in 1810.



LAND OF PLENTY

"Earth former" is what silicon has been called, for it is present in most all rocks, clays, soils, and even many semi-precious stones. More than one fourth the earth's crust is silicon—the most abundant element, next to oxygen. Electromet digs into mountain after mountain for high-quality silicon ore.



HOUSECLEANING SPECIALIST

Silicon does a "clean-up job" in iron and steel production, serving as both scavenger and deoxidizer. From the molten bath it removes harmful oxides and gases. Silicon is used for refining practically all alloy steels and many grades of carbon steel. It is second only to manganese in its usefulness in steelmaking.

A LITTLE AND A LOT

From about 0.20 to 1.50 per cent silicon goes into many structural steels—such as those used for highly stressed parts of bridges. In larger percentage, sometimes as much as 17 per cent, silicon equips cast irons to handle highly corrosive acids in chemical plants. Silicon also serves as a softener in cast iron.

MAGNETIC PERSONALITY

The heart of the mysterious transformer is made of steel containing silicon. Silicon is essential in sheet steel for electromagnets, generators, and other electrical apparatus because of the special magnetic and electrical properties it imparts to the steel. It has brought about tremendous power savings.

Cream Of The Crop

Electromet's interest in silicon dates back almost 50 years, for in 1898 the broad patent claims of de Chalmot were assigned to the Willson Aluminum Company, one of the predecessors of Electro Metallurgical Company. With its long experience in ferro-alloys production, Electromet naturally knows how to give all its customers alloys of high quality and purity. Write for the booklet "Electromet Ferro-Alloys and Metals," which will tell you more about silicon and the other Electromet alloys.

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Electromet

TRADE MARK

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Brittle Ships

(Starts on p. 514) plating and members or missing rivets, amounting to defects much greater than those which may have initiated disastrous failures in welded ships.

The Admiralty's committee early turned to a study of complete hulls, comparing the all-welded ship to a riveted ship of same design (hull shape, size, and compartmentalization). Two such ships were studied in still water, and cargo and ballast shifted to represent 14 different loading conditions. In this way it was determined that the main longitudinal stresses and deflections agreed fairly well with designers' predictions, but certain actual stresses were very high, due to local effects like bending of plating and changes in sections.

Next an experimental voyage across the Atlantic in the winter of 1944-45 was made with the riveted tanker. The ship was fitted with instruments to measure strains, deflections of the ship girder, pressure distributions in the hull, wave profile on the side, roll, pitch, acceleration, wind forces, and automatic cameras to produce stroboscopic pictures representing the state of the sea. It was found that the fluctuations in stress accompanying the movement of the ship in the particular seas encountered were surprisingly small, being only of the order of ± 2000 psi. The weather was severe, and it is unlikely that the worst weather could double this range. It must be borne in mind that these fluctuations are superimposed on whatever stresses exist in the ship under internal loads and cargo loads as she lies in still water, and unlooked-for stress concentrations would further increase the maxima.

This type of experimentation, to discover the behavior of complete ships' structures under dynamic conditions is still being vigorously prosecuted. A 10,000 ton all-welded cargo ship built in America has been fitted with an even more elaborate set of recording apparatus and made her first experimental voyage late in 1945. Once the most severe conditions encountered in service are known, the next and final step will be to subject two ships (alike except for seams) to loadings in still water that reproduce those conditions, and compare the respective responses.

Corrosion of Aluminum*

INHIBITORS for aluminum behave differently in various acids. The most effective types of inhibitors in dilute hydrochloric acid are soluble oils, wetting agents, amines and other nitrogen compounds. Chromates are not good inhibitors. In general, steel pickling inhibitors are likely to be effective inhibitors for aluminum in hydrochloric acid. Chromate is highly effective in preventing attack in phosphoric acid. Commercial soluble oils, wetting agents and amines are good inhibitors but not as effective as chromates. Nitrogen compounds or steel pickling inhibitors are less effective in phosphoric acid than in hydrochloric acid. Very small concentrations of chromates are effective in dilute nitric acid (under 20%). Good inhibitors for aluminum in sulphuric are unknown.

Likewise, no completely satisfactory inhibitor is available for sodium or potassium hydroxide solutions although some agents are stated to be reasonably effective. Alkaline carbonate or phosphate solutions can be almost completely inhibited by additions of sodium silicate but substantial amounts are required at temperatures near the boiling point. The most effective inhibitors in general are the silicates with a high ratio of silicate to soda. Fluosilicates, chromates, and permanganates also have some inhibiting action but they are not widely used. Sodium metasilicate can generally be utilized to inhibit the vigorous pitting in certain concentrations of some organic bases.

For waters containing small amounts of salts, the chromates, silicates and soluble oils are most useful. However, insufficient amounts of chromates may cause accelerated pitting. Sodium chromate is generally employed as the inhibitor in sodium chloride brines; sodium dichromate is used in calcium chloride brines which are usually somewhat alkaline.

One of the most difficult types of aluminum corrosion to inhibit occurs when aluminum is in contact with copper or some other cathodic metal in a solution containing chlorine ions. Soluble oils, silicates and chromates are satisfactory inhibitors *(Cont. on p. 522)*

*Abstracted from "Inhibitors of Corrosion of Aluminum", by G. G. Eldredge and R. B. Mears, *Industrial and Engineering Chemistry*, v. 37, August 1945, pp. 736-741.

Corrosion of Aluminum

(*Cont. from p. 520*) **for couples of aluminum and copper in solutions with 10, 50 or 100 p.p.m. sodium chloride, with the alkaline silicates the most effective. Tricresyl phosphates are the most effective in laboratory tests in preventing perforation of small aluminum cans containing gasoline and a synthetic sump water or sea salt solution. Protection, however, is best provided by a tank design to prevent water accumulation; it may also be provided by chromate inhibitor supplied in capsules or by an inhibitor-impregnated Alrok oxide film. Water may be an inhibitor in nearly anhydrous organic acids, phenols and alcohols.**

Leaded Gun-Metal*

PRACTICAL TESTS have been made to obtain data on gun-metals more suited both from the practical and economic points of view to the production of high pressure castings than the admiralty gun-metal or the 86% copper, 12% tin, 2% zinc alloy.

Additions of lead are known to promote pressure tightness but at the expense of mechanical properties, while nickel imparts improved mechanical properties. Experimental foundry tests showed that a leaded gun-metal with about 7% tin, 5% zinc, 5% lead and the balance copper, with or without nickel, is more adaptable to the production of pressure-tight castings of variable section than other lead-free or low lead content alloys, such as 86% copper, 12% tin, 2% zinc; or 88% copper, 10% tin, 2% zinc; or 86% copper, 7% tin, 5% zinc, 2% lead. Destruction tests showed that castings of this new alloy have bursting strengths at least equal to those obtained from the alternate alloys mentioned above. A nickel content of about 3% increased the bursting strength in one instance by about 30%.

Test bars of the new 83-7-5-5 alloy with less than 1% nickel, cast in dry sand, gave the properties shown in the table at the top of page 524.

***Abstracted from "The Use of Leaded Gun-Metal for the Production of Castings to Withstand Pressure", by Frank Hudson. Institute of Metals *Journal*, V. 70, 1944, p. 407 to 422.**

Leaded Gun-Metal

(Continued from page 522)

PROPERTIES OF CAST TEST BARS WITH 1% NICKEL

Proportional limit	about 10,750 psi.
0.5% yield strength	about 17,920 psi.
Tensile strength	30,700 to 42,230 psi.
Elongation in 2 in.	15.0 to 34.5%
Brinell hardness	60

Similar test bars on the nickel modifications showed:

	PER CENT NICKEL 0	3.5	5.35
Proportional limit	10,750	12,920	13,440
0.5% yield	17,920	20,830	24,415
Tensile strength	30,690	40,990	37,860
Elongation in 2 in.	15	21	9
Brinell hardness	62	70	85

The nickel modifications are better for elevated temperature service, but the nickel should not exceed 3 to 3.5%; otherwise age hardening may occur with possible embrittlement.

The new alloy has a specific gravity, coefficient of expansion and thermal conductivity practically identical with those of other gun-metals. There is practically no difference between this alloy and the 88-10-2 and the 86-12-2 gun-metals as far as corrosion by sea or fresh water is concerned. Wear tests have clearly demonstrated the superiority of this leaded gun-metal to the conventional 88-10-2 alloy in regard to bearing properties and wear resistance.

The leaded gun-metal has best casting properties when the gas content is very low; this is readily secured by melting under strongly oxidizing conditions. The optimum pouring temperature is similar to that used for the other gun-metals. The leaded alloy has better machinability than the lead-free gun-metals.

Silver Bearings*

USE OF silver bearings in aircraft engines has shown a marked increase in the past few years as a result of their excellent bearing capacity and fatigue resistance. When silver is properly prepared and bonded to the bearing backing, its resistance to fatigue is very high, comparable to that of any other known metal.

The silver should be as pure as possible with a *(Cont. on p. 528)*

*Abstracted from "Silver Bearings", by E. B. Etchells and A. F. Underwood. *S.A.E. Journal*, V. 53, Sept. 1945, p. 497 to 502.

Silver Bearings

(From p. 524) maximum hardness of Vickers 45 (15 kg.). The silver layer must be thicker than an ordinary babbitt layer. The bond between the silver and the bearing packing must be good. In present-day practice, both the electrodeposited and the thermally bonded types have been found to produce satisfactory results. Nickel is used as the bonding agent in the electrodeposited bearings. Heat treatment, as for stress relieving, is preferably done in a hydrogen-rich atmosphere but the silver must be oxygen-free to prevent embrittlement. Experimentally, a small number of bearings can be suitably annealed in a salt bath but heating in air will have a detrimental effect on the bond because of oxygen penetration.

When the thermally bonded silver strip is used, the bond is automatically tested in the bearing manufacturing process. After circle forming, the steel back can be heat treated for greater strength. Thin-walled bearings for aluminum crankcases can be made with stainless steel or bronze backings which give lower thermal expansion differentials. A final visual check on the bond can be obtained by indenting the bearing surface. The performance, especially in regard to embeddability of dirt, can be greatly improved by surface indenting and then filling or partially filling the indentations with lead alloy. Improved fatigue resistance and bearing performance are obtained by using the smallest practical indentations.

Years of observation and testing have indicated that the fatigue life of thin-walled silver bearings is about three times that of copper-lead bearings. Score resistance depends on the mechanical conditions of service as well as on conformability and embeddability. The score resistance of the silver is about double that of the copper-lead. Except for the grid type of bearings, the embeddability has generally been indicated according to the hardness. In embeddability, the silver is only about half as good as the copper-lead, but the silver grid is about twice as good. On the basis of resistance to corrosion by the acidity developed by the oxidation of highly refined mineral oil under normal conditions, the silver bearings are about four times as good as the copper-lead.